A VIEW OF THE COLORADO CAÑONS.

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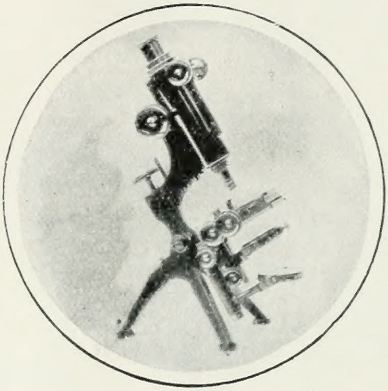
CASSELL'S . . .
POPULAR SCIENCE.



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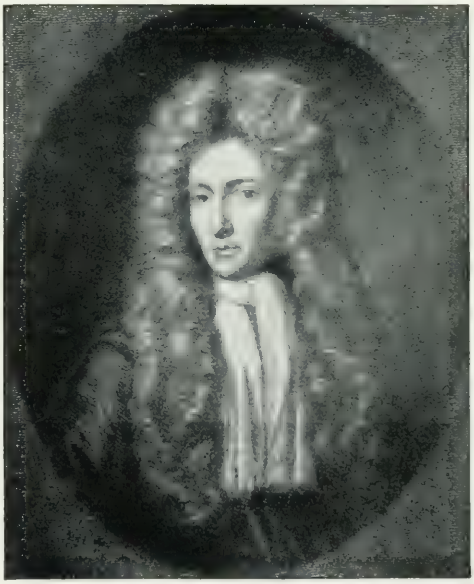
INTRODUCTION.

THERE have been many attempts made of late years to garb Knowledge in every-day attire, to render her ways less dark and devious to the ordinary individual. Yet it is to be feared that not all of these attempts have been successful, or else the idea that "popular science" may be read as "inexact science" had never been so widespread as it is to-day.

It may be that the ways of science, as generally expressed, are mysterious, and that the would-be investigator is appalled at the maze of technicalities and the disconcerting array of terms that confront him as he assays to gather some of that knowledge. Still, we may well ask ourselves the question, Why should these things be? Why should a statement be necessarily less exact, and therefore less valuable, because it is expressed in ordinary language instead of in a string of, to many, meaningless terms? Why must these same terms, frequently atrocious hybrids of Greek and Latin, be used at all? We may well ask why.



THE HON. ROBERT BOYLE, NATURAL PHILOSOPHER.

Born at Lismore Castle, January 25th, 1627; died, December 30th, 1691.

(From the painting by Kerseboom.)

CASSELL'S POPULAR SCIENCE is an attempt to give a decided negative to the idea that such things are invariably from necessity and not from choice. Where technical terms have been used they have been explained, so that their aspect becomes less appalling. There may be "no royal road to learning," but at least it is possible to smooth away many asperities from the ordinary path.

Is it worth while thus to simplify matters so that all may understand? Does not the Goddess of Science lose thereby some of her dignity? Will not "a little knowledge" prove, as of old, "a dangerous thing"? These are questions that may rise to the lips; and, as they are perfectly fair questions, I will try to answer them.

It *is* worth while to popularise. Knowledge of common things bulks largely now in every modern scheme of education. Let us be classical if we choose, poetical if we can, but practical we must be, and the truest science is

CARL LINNÆUS, THE GREAT BOTANIST.

Born at Rashult, Smaland, Sweden, May 23, 1707; died, January 10th, 1778.

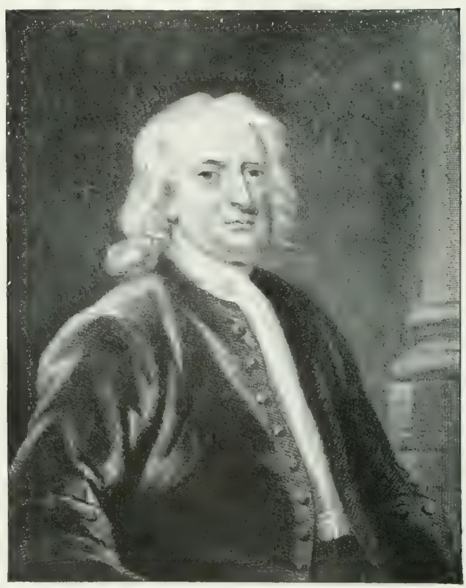
(From a copy by Pasch of the original at the Royal Academy of Sciences at Stockholm.)

nothing if it is not practical. Does the working engineer take any the less interest in the machine whose lot it is his to look to, because he understands the principles of which the machine is an expression? Will the farmer find farming less interesting, because he knows things which they of the old school knew not of or scoffed at? Rather will he not find the more of interest, and probably the more of cash, in his work, because of the deeper knowledge?

The so often quoted dangers of "little knowledge" can never affect the possessors adversely as long as they know it to be little. In that case the state of little knowledge will inevitably lead to greater things, and then nothing but good can result. Meanwhile, there is no reason why the little knowledge should not be garnered in pleasant fashion; the dignity of science will not be hurt in the slightest thereby.

Simplicity of phraseology, exactness in expression, and comprehensiveness as far as the limits of space will allow, have been the three guiding rules which have ever been before the writers of the articles contained within the covers of CASSELL'S POPULAR SCIENCE. The range of subjects is wide, for the fields of science are inexhaustible. Something has been gathered, much left for another harvest, yet it is hoped that the selection of subjects will be found representative.

It is my privilege to acknowledge much valuable assistance from Mr. T. C. Hepworth, whose articles upon the workings of the camera and the wonderful X-rays will be read with much interest; from Mr. Wilfred Mark Webb, in the direction of zoology; from Mr. J. Fraser, in the domain of plants; Mr. E. W. Maunder, of Greenwich Observatory, in matters astronomical; and Mr. J. O. Peet and Mr. C. W. Tisdale, of University College, Reading, in the way of agricultural science.



SIR ISAAC NEWTON, NATURAL PHILOSOPHER.

Born December 25th (o.s.), 1642, at Woolsthorpe, Lincolnshire; died at Kensington, March 20th, 1727.

(After the original picture by Vanderbank.)

One word about the illustrations. Pictorial representation is essential to the proper elucidation of knotty problems. An additional sense, that of sight, is called to aid in fixing scientific matters in the mind. It is not enough to *remember;* we want to *know* certain facts, and remembrance and knowledge are not quite the same, whatever is generally understood by them.

The most modern methods of illustration have been employed, and, wherever possible, the photographic camera has been utilised in portraying some of the innumerable pictorial wonders of Nature. Where tiny forms of organic life are concerned both microscope and camera have been brought into play. An exactness of detail has thus been obtained which could have been procured in no other way. Something of the further use of the camera in the making of printing blocks is described in Mr. Bale's article upon "Colour Printing" (page 32). The thousands of amateur photographers whom it is hoped CASSELL'S POPULAR SCIENCE will reach will thus have the subject of "photography in colours" suggested to them. To take a sun picture in all its natural hues would indeed be something to strive for. Some hints as to the way in which it may ultimately be done will appear shortly.

EDWARD JENNER, THE DISCOVERER OF VACCINATION.

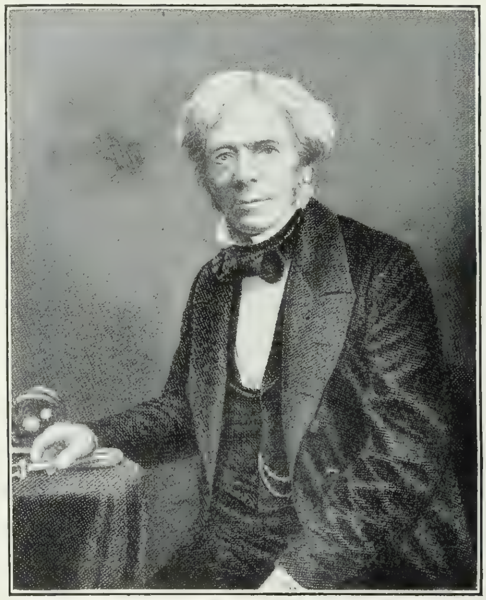
Born at Berkeley, Gloucestershire, May 17th, 1749; died at Berkeley, January 26th, 1823.

From a Painting.

The marvels of the midnight sky, with its galaxies of stars of the first, second, and third magnitudes; the glories of the "Milky Way"; the aberrant comets, which, fortunately for us, no longer speak of calamity strange and terrible to man; the shoals of shooting stars—the Perseids, the Leonids, and the Andromedes—have a fascination for many. Whence does the sun get its heat? Is the moon inhabited, or only a world destitute of organic life as we know it? What are the planets, and what the paths they travel? Those of us who turn to the star-spangled sky of a winter's night will ask for answers to these and many other questions. And we shall not be disappointed.

From the infinite greatness of the solar system to the infinite smallness of the minute organisms which lie at the foot, as it were, of the ladder of life may seem a wide range. Yet it is well within the scope of this work. Here the value of the alliance between microscope and camera stands manifest, for with our unaided sight we could do nothing. Day and night these humble yet industrious creatures are at work. Lowly and insignificant perhaps in their units, who shall withstand them in their myriads? They may devastate a continent with disease, or themselves act as the police agents of health and keep disease at bay. They are all around us and within us, ever vigilant, ever working. The dust of our streets is full of them; each loaf of bread upon the breakfast table

is a monument to their industry. How this can be is shown in the papers upon "Yeast," "The Chemistry of the Breakfast Table," and "Dust," to mention only a few. The articles upon "Milk," "Butter," and "Cheese" will be read with much interest and, I venture to say, with much profit. Why does milk turn sour? The housewife knows too well that it does. Now she may learn why. Is milk the wholesome food that it is claimed to be? is a question that is continually agitating dietetists. How is it that the deadly typhoid may lurk in its innocent-looking depths? Many a farmer knows how cheese is made; some of the rest of us have an inkling; but the dairy bacteriologist throws a new light upon these everyday affairs, and tells of wonders undreamed of.



MICHAEL FARADAY, CHEMIST, ELECTRICIAN, AND NATURAL PHILOSOPHER.

Born at Newington Butts, September 22nd, 1791; died at Hampton Court, August 25th, 1867.

Plant life is ever an alluring study. The work of the leaf, for instance, is a many-sided and complex one. If we read aright the story of "A Fallen Leaf," we shall know much that may be strange to us now. We all know that we, in common with other animals, breathe the life-giving oxygen, but perhaps some of us are inclined to grudge the exercise of the same function to the plant. Are plants desirable occupants of dwelling rooms? is a question frequently asked. How do they feed? and what do they feed on? are others. Then we may wish to know how it is that the innumerable forms of plants that clothe the earth have been distributed to their present quarters. What are the agents of distribution, and how do they work? These and questions like them are all answered in the pages that are to come. The mummy wheat is not forgotten. No one who has seen those shrivelled-up, black-with-age, mummified grains can have failed to ask the question, Can these dry things live?

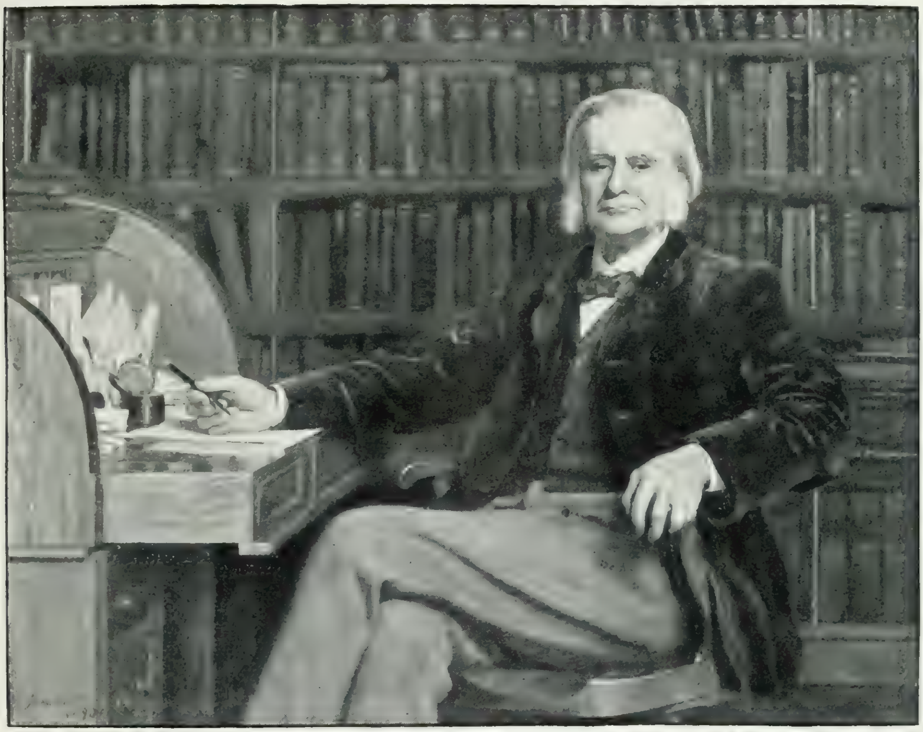
[illegible] Baker Street, W.

CHARLES ROBERT DARWIN, NATURALIST.

Born at Shrewsbury, February 12th, 1809; died April 19th, 1882.

The rocks of the earth have many a story to tell. The scars on hill and valley, now covered with the peaceful fruits of toil, speak with no uncertain voice of an age of fierce upheavals and sudden, far-reaching subsidences. Old Mother Earth is milder in her moods now, but that she has not quite forgotten those wild ways

of hers Krakatoa, La Soufrière, and Mont Pelée remind us. Meanwhile we will pluck the fossil from the cliff, examine the stones upon the sea beach, visit the quarry, climb the mountain side, delve into the river bed, or examine the kitchen-middens which long-vanished races have left us to show us how they lived, in the hope that we may learn something more of that far-away past when the face of the earth was not as we know it to-day. Even the piece of coal in the scuttle by the hearth has something for us and



From the painting by the Hon. John Collier.

THOMAS HENRY HUXLEY, BIOLOGIST.

Born at Ealing, May 4th, 1825; died at Eastbourne, June 29th, 1895.

we shall view it with renewed interest as we read of the huge sigillarias and lepidodendrons of the Carboniferous period.

Then, as the coal sputters and sends forth long streams of yellow smoke, to burst anon into gusts of fitful flame, the subject of coal gas will come naturally to mind. We shall want to know what it is, how it is made, why it gives a poorer light at some times than it does at others, even when the pressure is the same. "Air and Gas" carries on the story a little farther, and tells of the properties of gases generally, and especially of that all-important mixture, the air we breathe. And what, too, is liquid air? "The Conquest of the Air" follows close. Shall we ever fly as the bird flies? Or must we be content with the so-called dirigible balloon, which is helpless in a gale of wind?

Modern inventions open up an absorbing chapter. The phonograph, the biograph, and our new and lively friend "Teuf-teuf" represent the arts of peace; the deadly torpedo and the stealthily approaching submarine boat will do the

Photo: Elliott & Fry, Baker Street, W.
SIR WILLIAM CROOKES, F.R.S.,
CHEMIST.
Born 1832.

Photo: Elliott & Fry, Baker Street, W.
LORD LISTER, LL.D., D.C.L., F.R.C.S., ETC., THE INTRODUCER OF ANTISEPTIC SURGERY.
Born at Upton, Essex, April 5th, 1827.

same for the arts of war; and there are others to come. Electricity is a host in itself. What is electricity? A force is perhaps the reply, and that does not convey much to the average mind. Much will be told of its wonders as seen in the electro-magnet, the dynamo, the electric light, the telephone, and wire and wireless telegraphy. Our planet is encircled with a mesh of electric nerves. We light our streets and houses, send our messages, and convey ourselves and friends by the friendly aid of this subtle "force." The "how" will be apparent later.

Turning to the animal life of our globe, we shall read of the strange and terrible creatures that lurked in the streams and forests of the prehistoric ages—the mighty mammoth, whose bones are still preserved to us in fossil form; the monstrous reptilian forms of life, the curious dinotherium, now, to the sorrow of the scientist, extinct. Still these fossil remains will be pieced together for us and hypothetically covered with flesh and skin, so that we may at least be able in some manner to compare them with our living animals. Insect and animal histories will be traced with infinite care. We shall be told what is in a pond, and what in the sea; how a fish swims, and a bird flies; of forms of life that live upon the surface of the earth, and others that burrow below.

It may be asked, How is it possible to learn so much of what "science" is without going through the drudgery of mastering all the little details which are supposed to be necessary for students? The researches of Faraday, Newton, Herschel, Huxley, Darwin—and in our own day of men like Lord Avebury, Sir William Crookes, and Lord Lister—have made it possible. Portraits of some of these eminent scientists are here given, and they are representative of a whole band of willing workers for and staunch followers after wisdom. CASSELL'S POPULAR SCIENCE would not have been possible had it not been for the labours of these men and of others like them.

Photo: Jerrard, Regent Street, W.
LORD AVEBURY, D.C.L., LL.D., F.R.S., NATURALIST.
Born in London, April 30th, 1834.

CASSELL'S POPULAR SCIENCE.

HOW THE CAMERA WORKS.

By T. C. HEPWORTH.

HALF a century ago, when the photographic camera was a new thing to the general public, there was a mystery surrounding it, and this mystery was not dispelled for a long time. The power of producing from a small box a picture without the aid of pen, pencil, or brush was such a wonderful thing that it seemed almost akin to magic; and it is quite certain that this impression was so real that even educated persons would enter a photographic studio of that date with a feeling of something like awe.

There is not much mystery about the camera to-day, for its use has extended since those early years which saw the birth of modern photography; and now it is found not only in the hands of those who make a profession of photography, but in those of thousands of amateurs.

The title of this paper might seem to many a superfluous one, by reason of the circumstance to which I have already adverted—the disappearance of all mystery from the business of taking a photograph. But there are still many persons who have not attempted to take a picture by this means, and who are deterred from doing so by a fear that the operation involves far more technical knowledge than they would care to acquire.

Before we can fairly attack the subject, it is necessary to have a clear idea of what the camera consists; and when it is asserted that in its simplest form it need merely comprise a light-tight box with a small hole at one end, and that with such

Photo: Cassell & Co., Ltd.

FIG. 2.—TAKEN WITH A PIN-HOLE CAMERA.
Exposure: one minute.

Photo: T. C. Hepworth.

FIG. 1.—A CANDLE EXPERIMENT SHOWING THE INVERTED IMAGE.

a primitive apparatus a picture can actually be taken with the help of the sun's light, it will reassure those who are under the impression that photography is a complex study, and that its practice involves a quantity of expensive apparatus. There is certainly one advantage in approaching the problem in the way I propose. It gives the beginner an opportunity of seeing the why and wherefore of the various operations involved far better than he would if he started at once, with expensive apparatus, a full-fledged photographer.

Photo: J. C. Hepworth.

FIG. 3.—ROCHESTER CATHEDRAL FROM THE TOP OF THE NORMAN CASTLE CLOSE BY: BEFORE THE RESTORATION BY PEARSON IN 1891.
Exposure: one-twenty-fifth of a second.

Although photography only came into being about the middle of the nineteenth century, the camera—more familiarly known then as the camera obscura—had been in common use for a great number of years. Baptista Porta, a Neapolitan who flourished three hundred years ago, is generally credited with its invention; but it is now known that the principle of the apparatus was understood long before his time. That principle is summed up in the fact that it is possible to obtain an image, projected upon a surface by light, by means of a dark room, or box, with a small aperture in it. The thing can be easily verified in any room by closing up the window with a screen of brown paper, in which a small hole has been cut, and hanging on the wall opposite a sheet. An image of everything outside, displayed in the natural colours, will be seen upon the sheet. This image is inverted — a phenomenon which is explained by the circumstance that the rays of light which form the image, in going through such a small aperture, or through a lens, are subjected to a crossing of one another, which brings the top of the picture to the bottom of the sheet, and *vice versâ*. The experiment may be tried on a small scale in the way indicated in the accompanying picture (Fig. 1). A card is pierced with a small hole and held near a burning candle, with the result that an upside-down image of the candle and its flame is projected upon another piece of card supported near it. It will be evident that if, instead of such a card, we received the image on a surface sensitive to light action, we should take the first step towards securing a more permanent picture of the candle flame.

In practice it would be found much easier to use a box pierced with a hole. A cigar-box, made perfectly light-tight, will answer well for our purpose. It

should have a clean, $\frac{1}{4}$-inch diameter hole bored in the centre of one end, and this should be covered with a plate of thin zinc or copper, in which is bored a very small hole—say, the $\frac{1}{50}$th of an inch across. This hole should be temporarily covered with a piece of black paper; and before the box is finally closed a gelatine plate should be placed within it at the farther end, facing the readers if the exact circumstances under which it was produced are detailed. A card covered the end of the box employed, and this card was pierced with an ordinary pin—a "short white" is, I believe, the technical name of that sort of pin. It was hammered through the card while the latter was pressed upon a piece of lead, this being to avoid any burr being left round the hole—an important

Photo: T. C. Hepworth.

FIG. 4.—ROCHESTER CATHEDRAL: INTERIOR

Exposure: 45 minutes.

hole. This might be done by any friendly photographer. When the box is steadily supported opposite a well-lit subject—say, a statue in bright sunlight—and the black paper covering removed for about one minute from the hole, the gelatine plate within is impressed with an image which can afterwards be developed into what is called a "negative," from which any number of "prints" can be secured. A photograph taken by these simple means is shown in Fig. 2, and it will perhaps prove interesting to many thing. The exposure, or time for which the hole was uncovered, was one minute, on a sunny August afternoon, and a gelatine plate of the "rapid" variety was employed for the operation.

The tyro will probably at once ask, "If these things be true, why go to the expense of anything more elaborate?" The pin-hole camera, as it is called, is merely useful for the purpose of demonstration, and photography would have few professors if it were the only form of instrument available. Although, as we

have seen, we may secure a picture of a brightly illuminated object in about a minute, a portrait in a studio under the

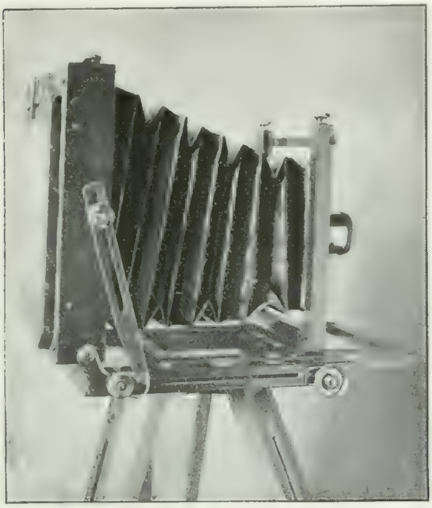


FIG. 5.—A STAND CAMERA.

best conditions would take a good deal longer, with the result that the sitter would probably not regard the picture as a success. In a word, pin-hole camera work is far too slow for picture-making, and many objects—interiors of churches and similar dark buildings—would be impossible with it. By furnishing the camera with a lens we at once conquer the difficulty, for we can then use quite a large aperture, and the lens so controls the light rays that the image is far crisper and sharper than when a pin-hole is employed.

It is noteworthy that Daguerre—who has been called the father of photography, although there are grave doubts whether he could properly claim that title—used a camera obscura, just as many other artists once did, to help him in sketching from nature. The apparatus consisted of a dark tent with a little table in the centre. At the top of the tent was a sloping mirror, which could be turned towards any point; and it reflected the image of the landscape outside, through a lens, to the table beneath, where the image was received upon a sheet of white paper, so that Daguerre, who was a scene-painter, could sketch over the lines formed by the action of the lens, and so get studies of trees, etc., for his professional work. A camera obscura of this type can still be seen at the Crystal Palace and some few other places of popular resort.

It is probable that a consideration of the structure of the eye gave the first idea of the camera obscura, for there is a close resemblance between the natural and artificial appliance. The eye has a lens in front of it, and the image formed by that lens is cast on a screen at the back of the eyeball, known as the retina. The camera has a lens, and at the back of it is a screen, upon which the image formed by that lens is received. The eye has a diaphragm called the iris, which opens and closes automatically with the volume of light to which it is subjected. The

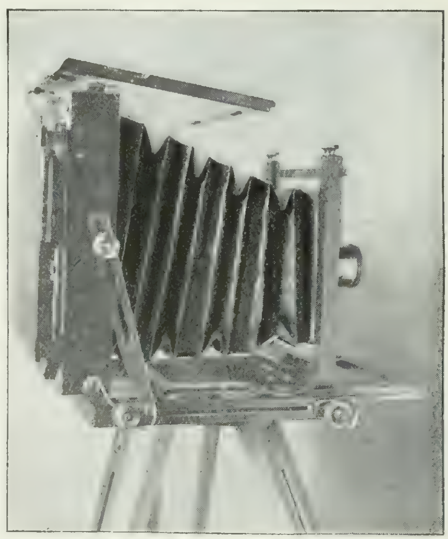


FIG. 6. THE DARK SLIDE INSERTED.

modern photographic lens has a diaphragm constructed on the same model, and it is employed for the same purpose.

The camera of half a century ago would

be laughed at now, for in comparison with the beautiful piece of mechanism now produced it was clumsy indeed—nothing more than a couple of boxes sliding one within the other, with a ground-glass screen at one end, upon which the image formed by the lens at the other end was received. The time of refinements in the art had not yet arrived, and the box arrangement answered all the needs of the professional worker and the few amateurs who at that time took up photography. It was anything but easy work then, for the process by which pictures were taken involved the use of a dark room or tent, endless bottles of chemicals, and a good supply of water. These things had to be all on the spot where the picture was taken, for development had to follow quickly on exposure, or the picture was spoilt. The birth of the dry plate process changed all this; it did away with the laborious part of the work, and made photography possible to the tourist and amateur.

With the advent of many recruits it was natural that improvements with regard to camera construction should be suggested and adopted. The old rule-of-thumb methods of working would no longer serve the purpose of those who took up the scientific study of photography; and now we find that a modern camera of first-class construction embodies so many little niceties of adjustment that it bears but a faint resemblance to the old box form of instrument. There is little wood employed in its construction beyond the mere framework, and that is now often hidden by a leather covering that makes the instrument far less obtrusive in appearance. The body is of leather, made like an accordion, and this gives the necessary lengthening out, which was formerly achieved by the boxes sliding one within the other. Such movement is necessary to the operation called focussing, and the best cameras are capable of very long extension, so that lenses of both short and long focus can be used on the instrument.

With a short focus lens the camera has to be shut up to a length of, say, five

Photo: T. C. Hepworth.

FIG. 7. A STREET SCENE.

inches, and with a long focus lens it may be racked out to a foot or more. In giving these approximate measurements, I have in view a quarter-plate camera—a camera, that is, which takes a plate measuring $4\frac{1}{4}$ by $3\frac{1}{4}$ inches. More cameras of this standard size are used than any other, one of the good reasons being that the plates cost only a shilling a dozen, and if a bigger picture be required the small negative can be easily enlarged.

I have hitherto spoken of the image formed by a lens being received on a sheet or other surface. In the photographic camera the image is projected upon the focussing screen, and by means

of the focussing screw the distance of that screen from the lens is governed. At a certain distance the image is seen to be sharply defined, or well in focus, as a photographer would say. The ground glass is then folded away, or altogether removed, and a case—called the dark slide—carrying the sensitive dry plate is put in its place. When a shutter in that dark slide is drawn out, the sensitive surface of the plate within receives the image previously thrown upon the ground glass screen, and the light does its wonderful work upon the plate.

FIG. 8.—DISTORTED REFLECTIONS

In Fig. 5 is shown a camera of modern construction, and its various parts will be easily understood from what has been already written. It will be noted that the base is a framework sliding in an outer frame, which is fixed to the tripod stand. It moves in and out for focussing purposes by means of a rackwork controlled by the mill-headed focussing screw on the right. In front of the instrument is the lens, screwed on to a square plate, which closes the end of the leathern bellows body. This plate can be slid up and down between the uprights, and can be fixed at any height required. At the back of the camera can be seen the ground-glass focussing screen. In Fig. 6 we see the same camera, but in this case the focussing screen has been thrown over the top on its double hinges, and the case or dark back carrying the sensitive plate now occupies its place.

I have used the word "plate" advisedly, although a glass plate is not the only thing nowadays which is used as a support for the photographic image. The introduction of the substance known as celluloid—a compound of collodion and camphor—has brought about a great change in the method of taking photographs, although "plates" are by no means superseded by it. Celluloid films, bearing, like the dry plates, the necessary coating of silver bromide emulsion, are procurable as flat sheets cut to the various standard (plate) sizes, or in long rolls. The flat sheets can be used in any form of camera designed for plates, and they have the great advantage of being extremely light and portable in comparison with glass.

The roll form of celluloid—which is like a long, broad ribbon—is used in a special form of dark slide called a roll-holder. This has a roller at each end, and the film is carried from one to the other behind the lens, so that the negatives are taken as each fresh length of celluloid is reeled off from one roller to the other. This is certainly the ideal method of bringing the sensitive surface under the operation of the lens; and, by reason of the light weight of the apparatus, it is invaluable to tourists, especially to mountaineers. I do not think, however, that the tyro would do well to start operations with celluloid films rather than

glass plates. Many will be deterred from doing so because of the extra expense entailed, celluloid costing about 75 per

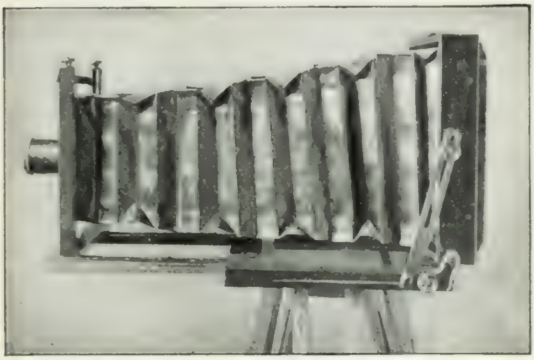


FIG. 9.—BELLOWS LENGTHENED TO THEIR FULLEST EXTENT.

cent. more than glass plates of the same area. A good plan to adopt is to get a camera which will accommodate itself to either plates or celluloid films, flat or rolled. Such cameras are now to be had. Other reasons why the aspirant to photographic success should begin his experiences with plates rather than films are that the former are easier to develop; they keep longer without deterioration; and what will perhaps appeal to him still more is the fact that plates are quicker in action. That is to say, that suppose a glass plate and a celluloid film are prepared in exactly the same way, by the same maker and at the same time, with the same sensitive emulsion, the plate will be more rapid than the film. Why this should be so seems to be somewhat obscure, but there is no doubt about it being a fact. I mention this circumstance because it is one that should be known; but the beginner would do well not to trouble himself at the outset with what are called " instantaneous " pictures.

There is a tendency among beginners—who naturally know little concerning the difficulties which surround working with the camera—to aim a little too high. They want to take what are called instantaneous pictures before they have attempted to learn the rudiments of picture-making. As reasonably might one expect a child to run before it has learnt to walk. Pictures of horses jumping at a steeplechase, of birds flying, of men diving, and the like, are, as we all know, possible with the rapid plates and mechanical aids now procurable; but for every successful result, how many failures can be counted? As is common with other sublunary things, we hear of the successes, but the unsuccessful attempts are not recorded.

To give one instance that came under my notice long ago. It was a splendid picture of a lightning flash. Now, such pictures are comparatively easy to secure, for the camera is left with the lens uncovered at night time—at an open window for preference—and the first flash which comes within the field of view is recorded automatically on the plate within. But vagrant flashes may

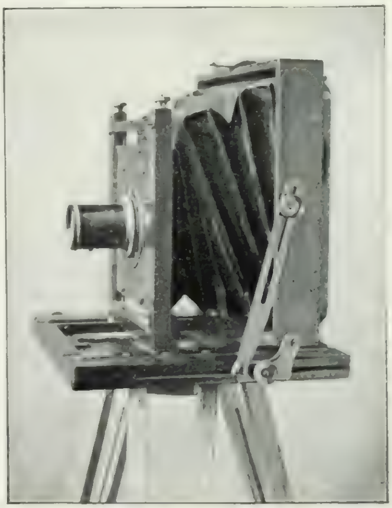


FIG. 10.—BELLOWS SHORTENED TO USE A SHORT FOCUS LENS.

come at either side, and while they leave no image on the plate, they spoil it by the brilliant light which they diffuse around. The owner of the successful

photograph just referred to candidly confessed that he had spoiled dozens of

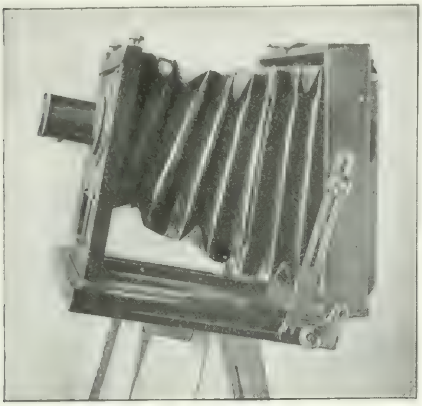


FIG. 11.—THE CAMERA WITH THE FRONT TILTED UPWARDS.

plates in this way before he was rewarded by this beauty.

On the other hand, it is by no means uncommon for a tyro to secure a successful picture at his very first attempt; and this I am inclined to look upon as a real misfortune to him, for he gains the erroneous impression that photography is the easiest thing in the world, and at once puts aside all notion of making a serious study of it. It is also a misfortune to a beginner to have a purse of such depth that the expenditure of any number of plates is a question of no moment to him. Such a person will fire away at everything, irrespective of its suitability for picture-making, and will be content if a reasonable percentage of his exposures turns out to be presentable when he sends his plates to be developed by the dealer whom he patronises. This means good business for both the dealer and the plate-maker, but it does not contribute to a man's photographic education.

And I may here point out that there is much misconception as to that word "instantaneous" as applied to photography. It really resolves itself into a question of available light at the time of taking the picture. For example, we may carry a camera some fine morning to Westminster and take a picture of the Houses of Parliament or the bridge in, say, the fiftieth part of a second. We may then step inside the old Abbey—supposing that we have obtained permission to do so—and take a photograph of one of the side aisles, or of a tomb. In both cases we may use the same lens, and a rapid plate from the same box as supplied by the dealers; but the interior view, instead of taking the fraction of a second, will very likely require the best part of an hour's exposure, or even more.

Turning for a moment to the other pictures illustrating this article, one (Fig. 3) depicts the exterior of Rochester Cathedral, photographed from the top of the ruined Norman castle which stands a few yards from it. The exposure given to this picture was the $\frac{1}{25}$th of a second. The other picture (Fig. 4) of the interior of the same building, taken with the same lens and under all the same conditions, with the exception of that of light, had an exposure of 45 minutes.

It will therefore be seen that one of the most necessary things for the budding photographer is to learn how long to leave his lens uncovered for different subjects, and this is governed by the state of the weather, the hour of the day, and the

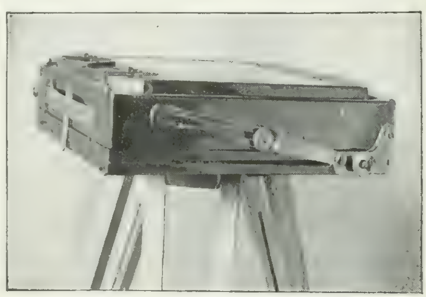


FIG. 12.—CLOSED: READY FOR PACKING.

time of the year. There are tables and other appliances to help in the work, but experience, after all, is the best guide.

If the beginner has possessed himself

FIG. 13.—GRIM AND WATCHFUL.

of an ordinary modern camera to be used on a tripod stand (I shall have something to say about hand cameras presently), he will do well to master the apparatus before he attempts to take a photograph with it. Screwing it on its stand, or attaching the stand to the turn-table which forms the base of the camera—a pattern of instrument to be much commended — and throwing the focussing cloth over his head, he will see on the ground-glass screen the inverted image of anything which may be in front of the camera. This operation should be conducted in the open air, if convenient ; if not, from a ground-floor window. The inversion of the picture will not trouble him except at first ; after a little practice he will forget that the picture is up-side down. A few turns of the focussing screw will bring the image to a sharp focus, and it will also soon be found how this is to some extent controlled by altering the diaphragm opening of the lens.

The camera should be kept truly level. Try the effect of tilting it up in front so as to include the top of some near building, and it will be found that the vertical lines are no longer vertical, but converge to a point. This, of course, would never do in the finished picture, and there is a provision against it in the camera in the form of a swing back, which carries the focussing screen. Keep the back of the camera vertical by this means, and although the base be tilted the lines will come right. Fig. 11 shows the camera in this position.

Another thing which will often be observed when we examine the image of a landscape or other subject on the ground-glass in the way described is that there is a preponderance of foreground, or possibly too much sky. This could be remedied by tilting the camera, but in that case we should get the lines out of the vertical. The right remedy is to shift the lens higher or lower, as the case may require, and most modern cameras provide the means of doing so.

Fig. 9 shows our camera lengthened

FIG. 14.—TAKEN AGAINST THE SUNLIGHT

Note the shadows in front of the children.

out to its full extent. The tyro, in purchasing an instrument, should insist upon having one which will thus lengthen out, for it gives him advantages which later on he will greatly value. For example, he may at some time want to copy documents, engravings, or small objects such as coins or medals; and unless his camera is capable of racking out to a good distance he will be unable to undertake such work, unless he is content to obtain very small images. Those who have old-fashioned cameras which do not lengthen out in this way have to get extension pieces to fit on in front of the instrument, which is, after all, a clumsy expedient, and therefore one to be avoided if possible.

Photo: T. C. Hepworth.

FIG. 15.—A WATERFALL IN BATTERSEA PARK.

In Fig. 10 we have the opposite extreme—*i.e.* the camera is closed so that the lens is brought very close to the focussing screen, for the accommodation of a short focus lens. It will be noted by comparing this picture with the others that not only has the front of the instrument been shut in, but the back has been advanced to meet it. This is necessary in using lenses of very short focus, or the front of the base board would actually be included in the picture. Short focus lenses are employed when it is necessary to take a subject at very close quarters—say, the interior of a room of small dimensions, or the exterior of a building from a courtyard. Fig. 12 shows the camera closed up and ready for removal from its stand for transport. It will be noted that, although it is capable of such elongation, it packs up into a comparatively small space.

"Shall I purchase a hand camera or a stand camera?" is a question which the beginner is very likely to ask; and the advice I would give is to obtain a camera which can be used in either way. A hand camera can often be employed under circumstances in which a camera on a stand would be of no use whatever; and, on the other hand, it may be quite useless for taking a much-desired picture. To give extreme cases: a stand instrument would be of little use in a small boat tossing on the sea, and one without a stand would not do for a church interior, or for any other subject requiring a protracted exposure.

The value of a hand camera cannot well be over-estimated for taking snapshots of street scenes, or snatching pictures which must be done on the spur of the moment or not at all. Such cameras are usually made without any focussing screen, the correct distance of the lens from the plate being indicated on an attached scale. But in order that the image may fall in the proper place upon the plate, a "finder" is attached, in which a reduced image is seen of the

view in front of the instrument. With a little practice and a steady hand, good pictures may be taken with a hand camera without reference to the finder. For several reasons it is best to aim at such a proficiency in hand camera manipulation.

It is quite a mistake to assume that a satisfactory picture can always be obtained with a hand camera, provided that the weather be favourable. The idea that the pressure of a button is all that is needed is a mistaken one ; and it will soon be found by the thoughtful operator that there is as much art is securing a really good snapshot, say, of a crowded street scene as there is in the manipulation of a stand camera. Indeed, in one respect the work is more difficult, for the persons photographed are quite oblivious of the operation, and the operator must choose the exact moment when accident causes them to group themselves in the way best calculated to form a good picture.

The cheaper forms of hand camera are generally fitted with a single (landscape) lens, and this lens is immovable, everything beyond a certain distance from the camera being always in focus. This arrangement is commonly described as a fixed focus lens. In the better class cameras the lens is of a far finer kind, and will represent perhaps half the value of the instrument. It will work at a far larger aperture, and therefore in comparatively dull weather. Effective street pictures, for example, have been taken in the rain, the wet pavements giving fine reflections. Besides this, the lens can be racked in and out, and close objects can be taken as well as distant ones. A hand camera should be easy of manipulation, the focussing arrangement, the shutter, the lens diaphragm, and the plate-changing mechanism being under quick control. There are many cameras in the market which have the most ingeniously devised contrivances for changing the plates or films, some of them being so constructed that it is possible to take any reasonable number of pictures without the necessity of resorting to a dark room.

The remainder of our pictures need no explanation. They have been selected with a view to show the variety of subjects which can be negotiated by anyone who possesses a camera and who knows how to use it.

Photo. J. C. H[illegible]

FIG. 16.—AT HAY HARVEST.

THE BIRTH AND UPBRINGING OF AN OYSTER.

By WILFRED MARK WEBB, F.L.S.

(Member of the Conchological and Malacological Societies.)

An account of the oyster dealing with nothing but its structural peculiarities would yet prove it to be a creature of no small interest. It is hardly possible, however, to look upon this bivalve from a single point of view. Since the time when man first wrote down his gastronomic fancies the oyster has been famous, and there is another proof of its celebrity more eloquent than words. Far back into the dim prehistoric past there runs a long line of empty valves, found often far inland, where primitive or later man has made his settlements. Even now there remains to be considered the industrial importance of the oyster, dependent upon this food value, as well as the possible danger to rash consumers from typhoid fever when sewage has contaminated the molluscs. Under these circumstances it would be difficult to pick out any allied forms so worthy of attention.

We shall deal, first of all, more particularly with our English "native" oyster (Fig. 1), and for a brief space consider important features in its anatomy, as well as the peculiarities of its early life.

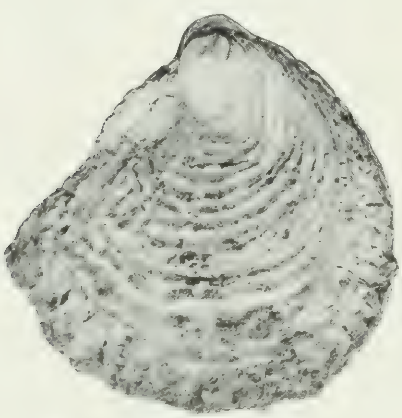


FIG. I.—A COLCHESTER "NATIVE."
(Ostrea edulis.)

The shell, though lacking the beauty of form and colouring found in that of many bivalves—such as its near relatives the escallops (*Pecten*) and thorny oysters (*Spondylus*) (Fig. 5)—has a characteristic shape. The oyster lies upon its left side, and the left valve, which is attached to some stone, shell, or other substance on the sea bottom, is saucer-like (Fig. 7), excepting that one of its edges is cut almost straight. The soft parts of the animal are snugly ensconced in the hollow of this valve, which is calculated to retain some amount of sea water should the tide leave the mollusc high and otherwise dry. The right half of the shell is probably more familiar, as upon it the oyster is allowed to rest when served up at the table. It is a little thinner than its partner, and flat; indeed, it fits into the latter like a lid. The similarity of the complete shell to a box is further borne out by the hinge, at which the halves are united by a ligament. This is the structure which, being elastic, causes the valves to gape open when the adductor muscle, running from one to the other in the live oyster, is suffered to relax. In an empty shell the scars marking the places where the muscle was attached are easily seen; and this is particularly the case in the American oyster (Fig. 2), for they are strongly pigmented, while the rest of the surface is white, giving to this species its well-known name of "blue point" (Fig. 6).

Many bivalves which are broader than they are long have two adductor muscles (Fig. 8), one at each end of the shell; and in days gone by, as we shall see, so had the oyster. The actual shell is brown

outside, being covered with a more or less horny layer. Experienced merchants claim that they can tell the kind of "ground" upon which the oyster grew

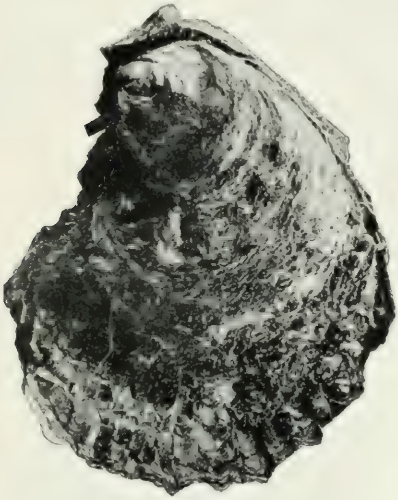


FIG. 2.—AN AMERICAN OYSTER.
(*Ostrea virginiana*)

from its outward appearance. Within, the shell is of a porcellanous character, the innermost layer corresponding to the "nacre" or mother-of-pearl of a "pearl oyster." If a valve be broken across it will be found that there is a middle portion, formed principally of lime, like the last, but showing more plainly its chalky character. Figure 9 shows a thin transverse slice of the shell of the fresh-water mussel.

To the epicure the oyster is but a luscious morsel, but to the anatomist it is a complex organism. Truly it has no head, but that does not prevent it from possessing a mouth (Fig. 10). This will be found to lie close to the hinge near the straight side of the shell. A short gullet leads into a stomach, and this is followed by a loosely coiled intestine. Circulation is effected by means of a heart, with a single ventricle and paired auricles, that lies just against the adductor muscle on the side towards the hinge. The auricles

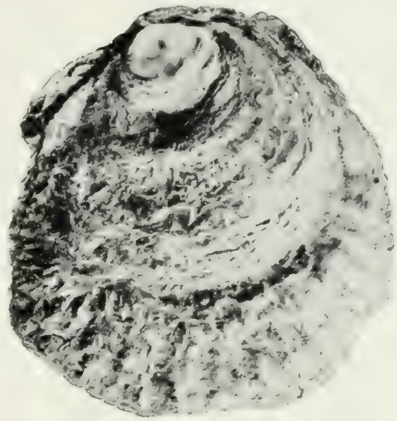


FIG. 4.—A FRENCH "NATIVE."
Bred in France from English "Natives," and brought to England when the size of a shilling.

receive purified blood from the large gills, or "beard," which follow the curved edge of the shell. Water is continually passing over the gills, currents being set up by means of little lashes, or "cilia," which are continually on the move. In a similar manner food, in the shape of tiny organisms, is swept into the mouth. A digestive gland surrounds the stomach, there are a pair of kidneys, and the nervous system consists of paired ganglia connected by nerves.

FIG. 3.—A PORTUGUESE OYSTER.
(*Ostrea angulata*.)

Contrary to the rule that holds good for bivalves in general and oysters in particular, the English species (*Ostrea edulis*, Linné) is hermaphrodite, each individual combining both sexes in its own person, as do the snails and slugs. The evidence is, however,

against an individual oyster being able to carry on the duties of both male and female at the same time, as is possible, apparently, in the escallop and watering-pot shell. Change of sex does not take place with sufficient rapidity to allow of anything but cross fertilisation, although this has often been set down as unnecessary. There is, however, a mass of conflicting statements still to be cleared away as to specimens becoming male first and female afterwards, or contrariwise. It is not certain also whether the change occurs during a single season, or whether the gentler sex claims an oyster one year, the sterner the next.

FIG. 5.—A "SPONDYLUS" OR THORNY OYSTER.

The embryo oysters have already gone through part of their development when we find them in countless numbers resting in the gills of their parent. To the naked eye they appear as white masses, which are shot out into the water if the shell is more or less rapidly shut. By the fishermen an oyster with the young at this stage is called "white sick," and the little ones themselves are known as "white spat." The latter, like all organisms which are not reproduced vegetatively, start from a single cell or "egg" (Figs. 11–16), which divides first into two (Fig. 12), and then more unequally into three cells (Fig. 13), while two of these cells continue to segment, forming many cells. The largest of them rests for a time, and, when it does ultimately divide, a depression is formed, which, becoming deeper and deeper, gives rise to the growth of the anterior part of the alimentary canal. A primitive shell gland is formed, and an external bivalve shell is afterwards secreted. In front of the mouth a projection or "velum" (Fig. 17) comes into existence, which can be protruded from the shell, and, being furnished with a plentiful supply of cilia, is the means of locomotion of the "veliger" larva. Further growth is characterised externally by the enlargement of the shell and a slight deposition of pigment in the tissues. This latter is very evident when the embryos are massed together, and entitles them to be called "black spat."

FIG. 6.—DARK MUSCLE SCAR SEEN IN A BLUE POINT.

FIG. 7.—THE LEFT VALVE OF THE OYSTER SEEN IN FIG. I.

It is at this period that the larvæ may, most advantageously to themselves, be expelled from the shell of the parent. The sudden closing of the valves is all that is required to send the members of the new generation upon their travels; the superfluous water rushes out in a stream, which carries away the "spat" with it.

The embryos now swim merrily about by means of their ciliated velum, and either fall a prey to some of their many enemies, or settle down, forming what is technically known as a "fall of spat." When it has once attached itself in some particular spot, the oyster loses its power of locomotion, and can never voluntarily move again.

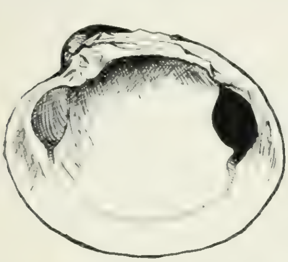


FIG. 8.—*CYPRINA ISLANDICA*, SHOWING MUSCLE SCARS AT EACH END.

In order to make clear an interesting point in the development of the embryo, it will be necessary to recall how the structure of the adult oyster has been modified from that of the usual bivalve type, such as the cockle or clam. In the latter both valves are equal and symmetrical, being closed, as already indicated, by two adductor muscles. One of these lies near the mouth and above the alimentary canal, while the other is situated below the latter and at the hinder end of the body. The oyster, on the other hand, is more circular in shape, and has but one muscle, lying below the alimentary canal. A series of bivalves could easily be arranged that would show the gradual enlargement (Fig. 19) of the posterior muscle at the expense of the anterior one, and it is safe to say that the oyster has lost the latter.

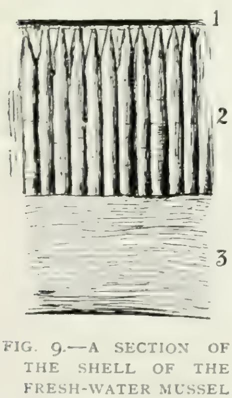


FIG. 9.—A SECTION OF THE SHELL OF THE FRESH-WATER MUSSEL (MAGNIFIED).

1. *Animal layer or periostracum.*
2. *Prismatic layer.*
3. *Nacreous layer.*

In the larva we find also a single muscle, but, oddly enough, this, it will be easily seen, corresponds to the anterior one of other bivalves, as it lies above the alimentary canal (Fig. 21). It follows therefore, as Huxley pointed out to Horst, that there must be a stage in the life history of the individual oyster which depicts what has taken place during the evolution of its race, where there are two adductor muscles, one on the wane and the other gradually superseding it. If such were not the case, we should have a bivalve which for a time would be in the uncomfortable position of being unable to close its shell.

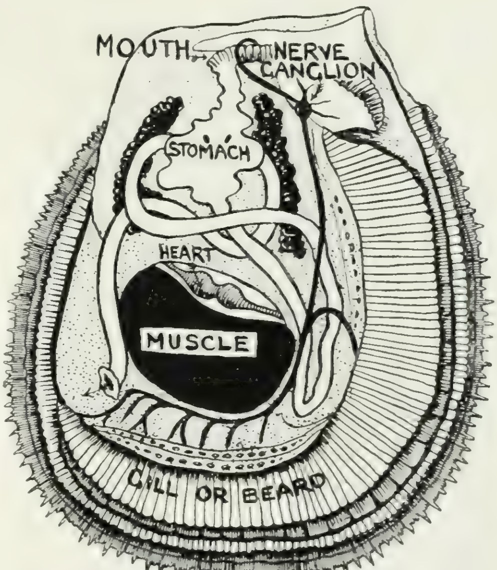
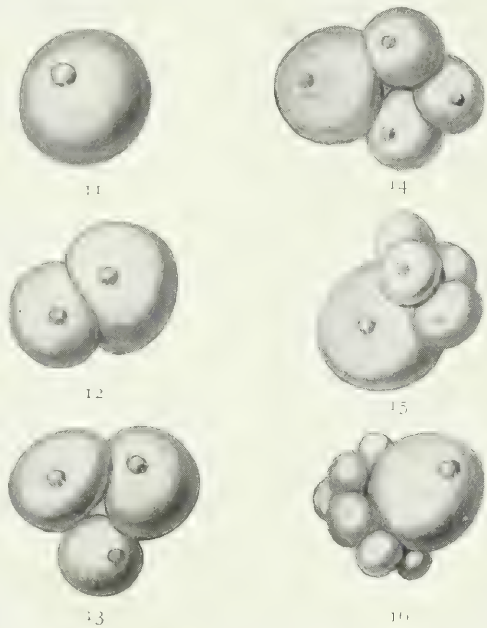


FIG. 10.—ANATOMY OF THE OYSTER
(*Modified from Möbius, Leuckart, and Nitsche.*)

Since Huxley forecast the existence of the stage in question, it has been discovered in the American oyster (*Ostrea virginiana*, List.) (Fig. 2), but not conclusively in the European species. There are many difficulties, as might be expected. The larvæ, in the first place, will not proceed with their development in aquaria, and in order to study them satisfactorily they must be induced to attach themselves to glass. Then, again, although oysters may be "sick" from May until November, the spatting season on our coasts is usually restricted to about

a fortnight of bright and warm weather such as we hope for in July.

The time during which the larvæ swim about before making up their minds to "fall" has been so variously estimated that the determinations appear at present to rest upon conjecture. In the Portuguese oyster (*Ostrea angulata*) (Fig. 3), the whole embryonic life, from the beginning of the segmentation of the egg until attachment takes place, was found to extend only to two days.



FIGS. 11–16.—DEVELOPMENT OF THE EGG OF AN OYSTER.

It was just after the embryo became fixed that the stage with two muscles was found in the American oyster by Tracey Jackson, and it seems likely that it may be discovered in our English species at the same period of existence. Horst, who succeeded in obtaining "spat" on glass slips, says nothing about it when describing them, nor does he give any sign of an anterior muscle remaining in the latest stages that he figures. The same observer was also unable to say definitely whether or not, as he was inclined to suppose, the larva anchors itself by threads such as are seen in the "byssus" by which the common mussel is attached.

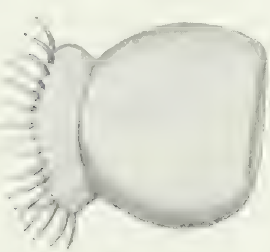


FIG. 17.—FREE-SWIMMING OYSTER EMBRYO WITH CILIATED "VELUM."

In the young oyster the edges of the shell away from the hinge are first applied to the surface chosen, and being rapidly added to by the deposition of shelly matter, the creature soon becomes easily visible to the naked eye. The veligers when swimming, say, in a glass tube, are distinguishable; but it is not, of course, until the "attached spat" stage (Fig. 18) that fishermen can recognise young oysters as individuals.

Naturally, and in "fisheries" where artificial collectors are not in use, the "spat" falls upon the empty oyster shells that pave, as it were, the breeding grounds, and are called "cultch." It will suffice to give details of one such "fishery" as typical of English methods, and we may choose that in the estuary of the River Colne, in Essex, celebrated for "Colchester natives," for which no better testimonial could be advanced than that their shells are found among the ruins of ancient Rome.

When the oyster is about as big as a shilling—that is, in its second season and a year old (Fig. 23)—it is termed "brood." This name appears to stick to it (Fig. 24) until it reaches its third year, when it becomes "half ware" (Fig. 25), in anticipation of the time when, after its fourth birthday, it is "ware," or a marketable oyster (Fig. 26).

Much trouble is expended in keeping the "cultch" clean, and in dredging up the "brood" in the private waters of the Colchester Fishery Company. The latter

process is carried out so that individuals may be separated from one another and from the substances on which they were "spatted." Afterwards, when returned

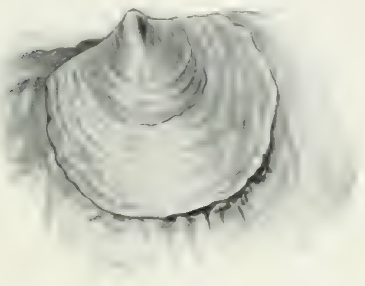


FIG. 18.—ATTACHED "SPAT."

to the water, the oysters are free to grow as naturally as possible, for a regular shell is wanted in Colchester natives which are destined for the market. The special shape of specimens from the Colne has been already described, and the prolongation of the side toward the straight edge is characteristic.

A good spatting ground is by no means of necessity the best fattening place for oysters, for the mud which may provide a wealth of food for the adult might very well smother the tiny "spat," even if it could find a hard surface for attachment. Hence when the breeding season is over fresh dredging operations take place, and

FIG. 19.—VALVES SHOWING THE DEVELOPMENT OF THE POSTERIOR ADDUCTOR AT THE EXPENSE OF THE ANTERIOR ADDUCTOR MUSCLE.

the four-year-old oysters are picked out and carried to an arm of the sea called the "Pyefleet," where they are laid down to fatten for the following season. A silver model of an oyster, belonging to the Colchester Corporation, is used as the standard size, no bivalve of smaller dimensions being considered saleable.

Even the rule-of-thumb methods that at present bring in a profit of some £8,000 a year have only recently been adopted. Previously the fishery, though outsiders were rigorously excluded, was of little value. The ancient borough of Colchester had its fishing rights confirmed in 1189. In 1727 their value was assessed at only £100 per annum; but then the cost of a

FIG. 20.—A BUNDLE OF TILES FOR THE COLLECTION OF "SPAT."

bushel of oysters was but 16s., whereas now it may be £12 or £14.

It has been found that oyster "spat" does not restrict itself by any means to the empty shells of its ancestors when it wishes to settle down. Sticks, stones, bottles, saucers, flint implements, and flat-irons, not to speak of old boots, are among the many objects to which oysters have been known to attach themselves, as shown by the collection which the late Frank Buckland got together. In France, for practical purposes, bundles of sticks, planks of wood, and strings of shells were among the first things tried. The chief trouble was, however, to prevent the "collectors," as they are called, from

becoming covered with mud or sediment, and roofing tiles have latterly been substituted. These tiles, as is well known, are curved, and it is found in practice that while the upper convex side may become

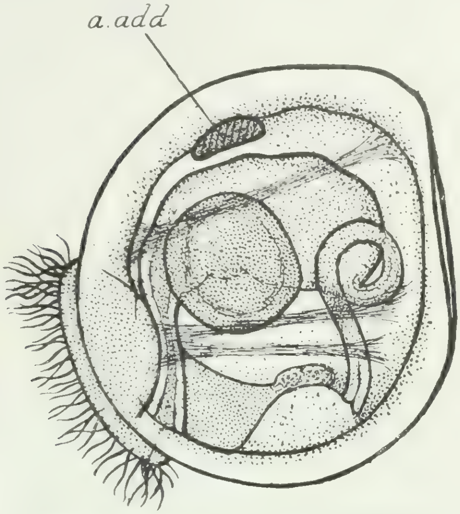


FIG. 21.—ANATOMY OF A LARVAL OYSTER.
(*Modified, after Webb.*)
a. add.—Anterior adductor muscle.

coated with slime and offer no hold for the attachment of "spat," the lower and concave one remains almost entirely free from sediment, and is the most successful of all collectors.

At first the tiles were subsequently broken up, so that each oyster was attached to a little piece, but to save expense the molluscs are now removed from the collectors. This process is rendered possible by dipping the tiles before using them into a composition containing lime, and the rough surface thus obtained has been found by experience to afford a better hold to the young oysters.

Crates full of tiles are used where the bottom is not soft and the water is so deep as to prevent the arrangement from being examined at low tide. Bundles of tiles (Fig. 20) strung together with wire are substituted in similar places, but where the water is deeper; these can be lifted up with a boat-hook. Should the bottom be too soft, a stake is driven in, upon which a bundle is slung so as to hang at a height of a foot or so above the mud. A series of wooden trays, similarly limed, are still often used in place of the crate of tiles.

In some places oysters have been successfully bred in enclosed ponds, as many as 3,000 spat being obtained on a single tile. The oyster cultivator either sells his "brood" or rears them himself. The first stages of rearing are profitably carried out in wire gauze cases, which prevent the tiny brood, often no bigger than a finger-nail, from being stifled with mud and preyed upon by their numerous enemies, such as starfish, boring molluscs, and predaceous fish. Larger oysters are kept in more or less elaborate enclosed areas known as "parks." Fattening is completed in small muddy ponds, and in these—for instance, at Marennes—"greening" takes place. Normally, this is apparently due to green diatoms upon which the oysters feed, and according to connoisseurs an exceedingly fine flavour is the result.

In America oyster culture on modern

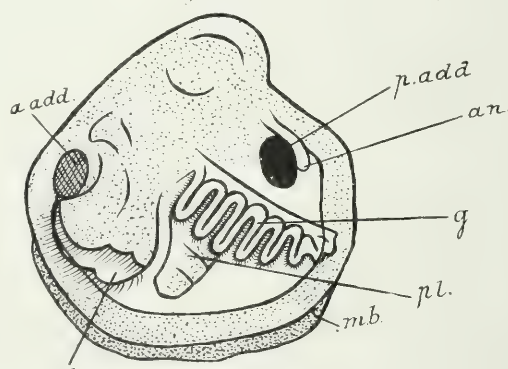


FIG. 22.—A YOUNG AMERICAN OYSTER.
(*Modified from Tracey Jackson.*)
a. add.—Anterior adductor muscle.
p. add.—Posterior adductor muscle.
an.—Anus.
g.—Gills.
m b.—Mantle border.
pl.—Palps.
v.—Velum.

principles is thoroughly carried out; in Belgium the rearing of imported brood is the main part of the industry. From the time of the people who made the "kitchen

middens," the oyster has been popular in Denmark. In 1884 the Government, which has the monopoly of oyster culture, had, owing to the depletion of the banks, to forbid "fishing" for five years. Now the industry seems in a fair way to be developed. Although France produces the most "brood," Holland undoubtedly rears the largest number of adult oysters.

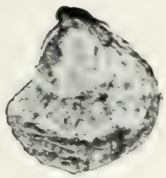


FIG. 23—A YEAR-OLD COLCHESTER NATIVE—"BROOD."

Turning once more to England, we find that at present the Colne Fishery Company make up their stock by buying "brood" from outside fishermen, who dredge it up on the common grounds outside the Corporation's jurisdiction. It has, however, been conclusively proved that the tile method ought to be adopted in the Colne estuary, and this by a series of experiments conducted by the Essex County Council with the help of a grant of money from the Colchester Corporation. Little or no spat was obtained at first by the expert employed, but by adopting similar methods (bundles of tiles) in a more suitable place the biological staff of the Council, which established a temporary marine biological station at Brightlingsea, met with unqualified success. The last spot chosen for the trials was outside the boundary of the Fishery Company, and it was estimated that if the common grounds were brought under a rational system of cultivation the whole rates of the county might be paid by the proceeds.

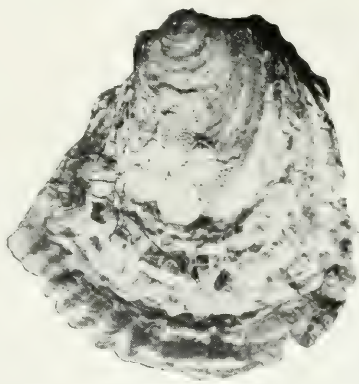


FIG. 25.—THREE YEARS OLD AND STILL GROWING—"HALF-WARE."

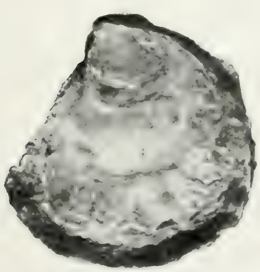


FIG. 24 TWO YEARS OLD AND HEALTHY—"BROOD."

There is another phase of oyster culture to be met with in the Colne estuary. All the creeks do not belong to Colchester. The one at Brightlingsea, for instance, is divided up into "layings," which are in the hands of private oyster merchants. These buy oysters in the brood or later stages, in order to rear or fatten them as the case may be. Brood may be brought from France, where it has been bred from English parents, and it grows into the so-called "French natives." The shell of these (Fig. 4) does not show the lop-sided appearance to anything like the same degree as the Colchester native, and the mark of attachment to the collector can easily be distinguished. Some of these oysters grow very rapidly. American "blue points" may be laid down for some

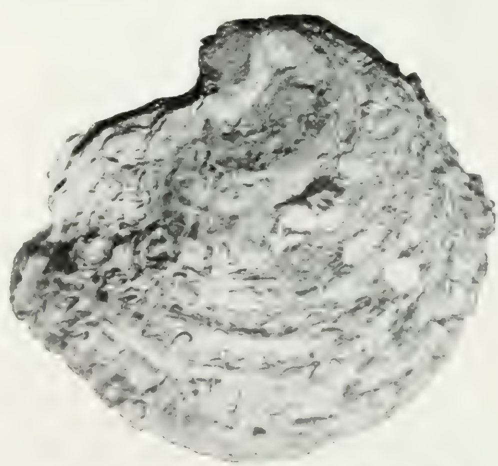


FIG. 26.—FOUR YEARS OLD AND READY FOR MARKET—"WARE."

time. These often contain the interesting little pea-crab, and are more liable than other species to a disease giving them a green appearance—not due to diatoms, however, but to an excess of copper in the blood. Lastly, the Portuguese oyster, with its deep lower valve recalling the more elegant fossil *Gryphæa*, is fattened on our coasts.

It is the oysters placed in "layings" adjoining a town, from which sewage is allowed to flow over them, that are most liable to convey the bacilli of typhoid fever. The water of the open estuary of the Colne proved, upon bacteriological investigation, to contain few germs of a questionable character; while that of the Pyefleet, where the oyster is fattened, epicures may be pleased to learn, was still purer. A few remarks upon oysters and the spread of disease may aptly bring this paper to a close.

As early as the year 1839 oysters were accused of causing cholera, and since then they have been, from time to time, thought to give rise to typhoid fever. In 1893 the Medical Officer of the Local Government Board became convinced that oysters played a great part in the spread of cholera from Grimsby and Cleethorpes, there being evidence that the oysters in the "layings" there must have "almost necessarily" been bathed at every tide with sewage containing cholera germs. About the same year a number of outbreaks of typhoid fever in America were pretty clearly traced to indulgence in oysters.

The scare which followed naturally damaged the oyster trade very severely, and it was put down by merchants as one of those excitements said to be periodically created by the medical profession to show how carefully it looks after the public welfare. It requires little knowledge of oyster cultivation on our coasts, however, to demonstrate how likely the doctors are to be right; and the inquiry of the Local Government Board showed conclusively that, while all danger might be obviated if proper precautions were taken, yet hardly any "layings" could be put down as being theoretically free from any possible chance of sewage pollution. Some were characterised as being filthy in the extreme. Furthermore, the bacteriological investigations which formed part of the same inquiry showed that the typhoid bacillus could be found alive and unchanged in (1) flasks of sea water, after four weeks; (2) three-gallon tanks from which one-third of the inoculated contents was daily replaced by ordinary sea water, for two or three weeks; (3) oyster bodies carefully emulsified after being kept alive in infected water, on and up to the seventeenth day.

The cholera vibrio lived as such for two weeks in sea water, but in subsequent experiments its powers became somewhat modified.

Outbreaks of typhoid will probably continue from time to time to create "oyster and typhoid" scares. The medical officer of health for a borough in which a scare recently occurred gave it as his opinion that many of the cases were directly attributable to the eating of oysters from certain beds. In defence of these oysters it was pointed out that the quantity of sewage that found its way into the beds was very small in proportion to the volume of water, and that it was probable, therefore, that they were not the medium by which the disease was spread. At present there still exists some diversity of opinion on the question. Whatever may be ultimately established by the investigations of the experts, however, there can be no doubt that the importance of keeping oyster beds free from sewage contamination will in future be insisted on. There is no danger to be feared from eating oysters taken from unpolluted beds, but when typhoid germs are conveyed to the beds by sewage the result is disastrous.

METEORS.

ANYONE who watches the sky on any evening of ordinary clearness, when the stars are shining with some brilliancy, will observe one or more luminous objects in rapid motion amongst the constellations. Such "shooting stars," as they are called, often attract the attention of the most casual observer, either by their numbers or splendour. The suddenness of their appearance, the bright light they sometimes throw over the landscape, and the rapidity with which they travel athwart the sky, occasion surprise; and as the observer's eye still lingers on the place of apparition his interest is excited, and questions arise in his mind as to the origin and nature of these remarkable bodies. Whence do they come? Whither do they go? What are their magnitudes, distances, and velocities? If he pursue his observations with any diligence, he will have noticed that some are visible on every clear evening; and that, as surely as the darkness comes on and the constellations begin to show, so surely do some of these falling stars manifest themselves. They present every variety of speed and appearance. Some glide along the sky with a slow and stately motion, remaining visible for several seconds, and allow their paths to be conveniently traced. Others are seen to move in extremely quick and transient courses, like flashing rays of light. Some speed along in star-like aspect, devoid of trains or sparks, while others will be seen to leave in their tracks phosphoric lines or streaks, perceptible for some seconds, and distinctly marking the direction of the paths. A few will be noted to move apparently upwards in the sky, and there will be others with nearly horizontal courses; and many will be descending in oblique and vertical paths towards the horizon. Our observer, as he attentively views their irregular and complicated motions, will be impressed that these objects are not following any laws capable of being reduced to the same harmony as pervades the solar system. This, however, would be quite erroneous, for the behaviour of these meteors is beginning to be as well understood as that of celestial objects which have been observed from the earliest ages.

By persistent observations, made night after night and year after year, it was found that shooting stars diverged from certain definite points in the sky. Tracing the observed paths back in the same direction of motion, it was discovered that they intersected at a focus, known as the *radiant point*. This was especially noticed on certain nights in August and November, when meteors were seen in great abundance. The great majority of the meteors, no matter in what region of the heavens they appeared, were all directed from the same part of space, and exhibited many features in common. They diverged, like the spokes of a wheel, from a common centre (Fig. 1). In 1799, on the night of November 11th, Humboldt and his fellow-traveller, Bonpland, witnessed a great fall of meteors; and in 1833, when on the 13th of November the phenomenon recurred with much splendour, it was remarked that the vast majority of the meteors had the same point of departure in Leo, near the star *Gamma* of that constellation. It was therefore suggested that they belonged to the same system, and occurred periodically at intervals of about thirty-three years; which more recent observations have fully borne out, for on November 13th, 1866, there was another brilliant display of meteors. In August,

FIG. [illegible]. A SHOWER OF METEORS.

The point from which they appear to radiate is known as the "Radiant Point."

too, on the night of the 10th, a large number of these objects had often been observed. Their apparition on St. Lawrence's Day caused them to be known as "St. Lawrence's Tears"; and it was re-

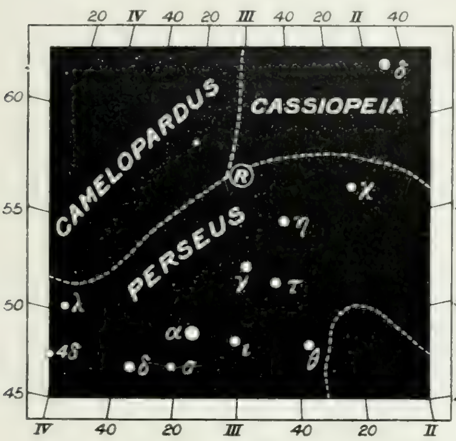


FIG. 2.—PERSEID RADIANT

marked that in this case the point of departure was in Perseus, and that the phenomenon returned every year with much regularity and intensity: in this respect differing from the falling stars of November, which seemed to be more periodical in character. Another meteor shower of great intensity, with its radiant point near the right foot of Andromeda, was witnessed on December 7th, 1798, and on December 6th, 1838, and the members of these several systems were designated after the constellations from which they emanated. The August meteors are now familiarly known as *Perseids*, the November meteors as *Leonids*, and the meteors of 1798 and 1838 as *Andromedes*.

As observers began to pay more attention to this subject it was soon found that, in addition to these rich meteoric displays just mentioned, many other systems of a like nature were manifested, though of minor importance. Star showers of more than usual significance had been recorded on the nights of January 2nd, April 20th, October 19th, and December 12th; and as further observations were made it was sought to explain the apparition of these singular objects. Many facts about them tended to puzzle theorists, who had very scanty materials to work upon. When Heis, in 1833, began systematically to observe and record the directions of shooting stars, he entered into an entirely new field of research. Before his time they were seen in a vague, careless way, and seldom recorded with any fulness or accuracy. They were considered to be purely atmospheric phenomena, and of little importance. It is, therefore, not to be wondered at that the ideas prevailing were of the most crude and uncertain nature. Some imagined that they had their origin in phosphoric fluids, which ascended from the earth's surface at various points, and became visible when, having become decomposed in the higher regions, they had taken fire, the ignition extending itself rapidly backwards to other parts of the column, until it came to a moisture-laden current, which extinguished it. Thus, for instance, in Keith's "Use of the Globes," of which a new, enlarged, and improved edition was

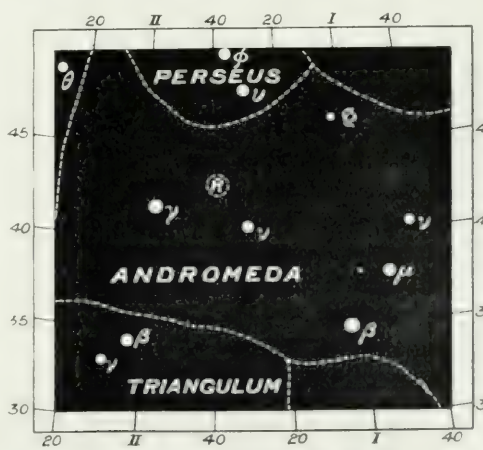


FIG. 3.—ANDROMEDA RADIANT.

issued by the Rev. G. N. Wright, M.A., in 1840, it is said that "the falling stars and other fiery meteors, which are frequently seen at a considerable height in the atmosphere, and which have received

different names according to the variety of their figure and size, arise from the fermentation of the effluvia of acid and alkaline bodies which float in the atmosphere. When the more subtile parts of the effluvia are burnt away, the viscous and earthy parts become too heavy for the air to support, and by their gravity fall to the earth."

It was further sought to establish a connection between these falling stars and gales of wind, for there are passages in old writers showing the idea to have been very prevalent. Another theory, which also had a section of adherents, ascribed a lunar origin to aërolites and meteors. They were said to be ejections from the volcanoes in the moon, and that, occasionally coming within the sphere of the earth's attraction, they were drawn towards her surface. But these ideas gradually gave way to the more reasonable hypothesis that they were of celestial origin. To account for their luminous appearance it was suggested that on entering the earth's atmosphere the concussion was so great as to ignite their combustible materials, and they were wholly consumed before reaching the earth's surface. The smaller class of these bodies would, no doubt, be soon dissipated in the upper regions of the atmosphere; but it was thought doubtful whether the ordinary shooting stars belonged to the same order as the large meteors and fire-balls and required the same explanation.

Our knowledge in this branch was, however, most unsatisfactory when, in 1833 and for several years at about that period, there occurred a succession of remarkably fine meteoric showers, which excited the interest of all ordinary gazers, and, what was of more importance, diverted the attention of astronomers from other subjects. Professor Olmsted witnessed the bright display of 1833 in America, and was led to collect observations made at many different stations with the view to throwing some light upon the subject of these falling stars. His investigations led him to infer that they had their origin beyond the limits of our atmosphere, because the point of the sky from which they fell apparently moved with the stars. If the meteors had their origin within the atmosphere, they must have been carried along with the earth in its diurnal rotation. He also concluded that the meteors were combustible bodies, constituted of light and transparent materials, and said that when massed together they formed a body bearing a strong analogy to a comet. From this he was led to ask whether the meteor shower was caused by a comet which "chanced at the time to be pursuing its path along with the earth around their common centre of motion."

This theory as to the origin of the Leonid star shower was evolved by Prof. Olmsted in 1834. Two years later M. Quetelet, of Brussels, showed that the Perseid shower of August was also periodic, and was therefore, according to Olmsted's theory, due to a cloud of cosmical particles which revolved round the sun in a period of a year or a sub-multiple of a year. In 1839 Adolf Erman, of Berlin, suggested that the meteoric particles revolved round the sun in closed rings, not as a single cloud; and at this point all researches in the subject were dropped until the great November shower of 1866 brought them again into notice. Then an actual identity was established between the orbits of several comets and meteor showers. The eminent Italian astronomer Schiaparelli showed that the August meteors were directed from a point in the heavens at which the earth encountered the third comet of 1862. The elements of the two were almost coincident; and it was soon afterwards pointed out by Dr. Peters that the November meteors corresponded to the first comet of 1866. A third, and in some respects even more interesting, connection came to light in the case of the

Andromede meteor shower, for this proved to be travelling on the same path as Biela's comet, which had been actually watched in the telescope dividing into two distinct bodies in the last few days of 1845. Other evidences of the strong disruptive agencies to which comets are exposed have been numerous since that time. Several bodies broke off from the head of the great comet of 1882, whilst the photographs of Swift's comet of 1892, and of Rordame's, and of Brook's of 1893, show knots and streamers in their tails, or, in the case of the last named, a twisting and distortion as if the comet were meeting a heavy gale of wind. It is possible, therefore, not merely that comets and meteor streams may travel together in association on the same paths, but that the meteors may actually be formed by the gradual disintegration of the comet's structure.

These important discoveries lent a new interest to the subject, for they put beyond doubt what had for a long time perplexed astronomers. They proved that shooting stars play an important part in astronomical physics, coming, in fact, from the interstellar regions. Though extremely small, they exist in planetary space in vast multitudes, and compensate for their smallness of size by their great numbers. The original cometary systems from which they are distributed would appear to be in process of dissipation, or wasting away, for it is impossible to conceive that a body will not suffer diminution when it casts off such a large number of its particles as fell towards the earth during, say, the great meteoric shower of November 27th, 1872. But such a process must be very gradual; for though, to our conception, the number of meteors that fall is vast indeed, yet it is trifling when compared to the illimitable supply from the parent systems, and the density with which they are found scattered over a long range of their orbits. Thus, in the case of Biela's periodical comet, which supplied us with the fine meteoric displays of 1798, 1838, 1872, and 1885, it is certain that for at least 500,000,000 of miles along the orbit the particles were extended in rich profusion, and sufficient to give a display of much splendour whenever the earth encountered it. Professor Kirkwood has pointed out that in 1838 the earth intersected a part of the comet's orbit fully 300,000,000 of miles in advance of the nucleus, and in 1872 the earth was immersed in the rear some 200,000,000 of miles.

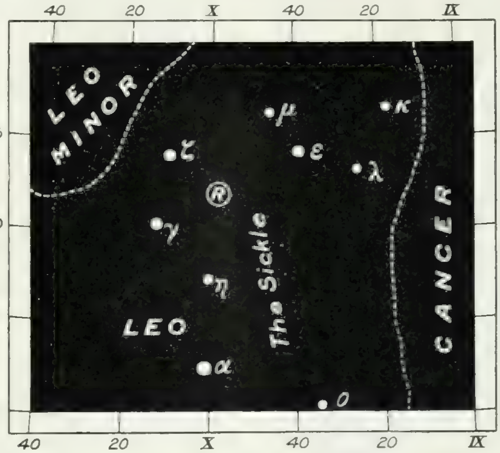


FIG. 4. LEONID RADIANT.

It is evident, therefore, that if, at a point so distant from the real body of the comet, the particles are so thickly strewn as to present showers of considerable intensity, we might expect in the event of the earth's collision with the actual nucleus of a comet a meteoric display or illumination far beyond the experience of anything recorded in our annals. The heavens would be alive with the swarming and seething of a vast host of falling stars chasing each other in densely packed ranks, and exhibiting a symmetry of motion most beautiful to behold. Fire-balls of great size and rare brilliancy would be mingled with a thick rain of meteoric dust, suffusing the whole sky. Near the point from which they came a number of stationary meteors, like transient stars, would be seen ; while in a circular area a few degrees distant a fringe of meteors would appear with very short paths. Farther off, and in regions removed from the radiant point, none would be seen but those with long, graceful courses ; and these would exhibit greater speed than the rest, and generally be more conspicuous. Never more than on an occasion like this should we be thankful for the protection afforded us by our atmosphere, which would be certain to act as an impenetrable shield and destroy by combustion the meteor particles as fast as they came on. Evidently, therefore, the earth could suffer little in an encounter with a comet : the latter would be certain to get the worst of it. Not only would the comet experience a considerable loss of its materials, but its path must be greatly affected by the earth's powerful attraction, and henceforward it would pursue a new orbit ; for we know that cometary motions are much liable to perturbations if they approach near a planet. Jupiter is a frequent disturber of cometary orbits, for his great mass cannot fail to exercise itself strongly upon the light and thin materials of their composition. But, though the earth has never yet been known to meet with a comet, the great meteoric storms that have sometimes been witnessed were signs that a comet was not far off. There is, however, nothing impossible in such an encounter, though it is highly improbable ; and some alarm was created in 1832, when it was announced that the nucleus of Biela's comet passed within 20,000 miles of the earth at a point which the earth would occupy on December 3rd in that year. But the comet arrived at the place about a month before the critical date, and hence a collision was avoided.

It has been stated that certain of the principal meteor showers agree in the most conclusive manner with the orbits of periodical comets. This is the case in regard to the meteors of April 20th, August 10th, and November 13th and 27th. But it must not be assumed, therefore, that all the phenomena of falling stars are to be explained at once on the same grounds. Certain anomalies have been pointed out which render it difficult to harmonise theory with observation. In the cases alluded to not even the most sceptical would fail to admit the wonderful agreement in the meteor and comet orbits, and must accept the identity as beyond question ; but in a vast number of other instances no such convincing coincidences are to be met with. The observed duration of many showers is far beyond the limits assigned to them by theory. Those who have worked most diligently in the department of observation affirm that some of these meteor systems continue visible for a month and more. In some cases, indeed, the time extends over two months, and even beyond that occasionally. Now, it is certain that a meteor shower brought about by the intersection of the orbits of the earth and of a meteoric swarm can last only a few days (except in a special case, when the

duration may be longer), and that there will be a short period of maximum intensity. The earth in her orbit travels over about one and a half millions of miles

FIG. 5.—TRAILS LEFT BY A METEOR SEEN ON OCT. 19TH, 1877.

in a day, and hence must very soon make her passage through the meteor stream, unless it has far wider proportions than is considered probable. In the case of the several systems specially referred to as agreeing with comets the shower of meteors is of very short endurance, and seldom exceeds one or two nights in its real intensity; and should the shower—as in the case of the Perseids—be visible for several days, then, since the earth travels in a nearly circular orbit round the sun, the curvature of its path causes a constant change in the angle at which the orbit of the meteors encounters it, and consequently the radiant point seems to slightly shift its place in the sky night after night. In this it conforms precisely to what theory teaches.

But how shall we explain in the same way a meteor shower continued from an unshifting—*i.e.* a fixed—radiant point during several months? Obviously, the observations are false or the theory requires modification. The difficulty may, to some extent, be got over if it is granted that these meteor streams have each become scattered, or widened out, over a vast space by the annual effects of the earth's attraction as she sweeps through them. This having been going on for many ages, it is probable that they must suffer considerable distortion; and if this is what has actually taken place, without any material displacement of the radiant points, we can understand how these long-continued showers have their origin. At present it has been attempted to account for them on the supposition that each one consists of several distinct systems succeeding each other from the same directions, but the explanation is untenable in the face of the numerous and exact observations supporting a contrary view. Meteors are often seen coming from the same points in the sky for two months or more, almost without apparent cessation, and it is only fair to conclude that they are in some manner connected. If our present ideas as to the nature of meteor orbits cannot explain observed facts, then they must be re-

FIG. 6.—METEOR SEEN NOV. 12TH, 1861.

modelled on the basis which those facts supply. It will never do to make observation subservient to theory, or we shall have a bad precedent, and one which can only tend to stultify original research. Our knowledge in this department is

admittedly very recent and incomplete. We must continue for many years to gather materials, taking as little as possible for granted, and bearing in mind that there is great variety displayed throughout the planetary system, and that in the great assemblage of meteor swarms enveloping the earth we may

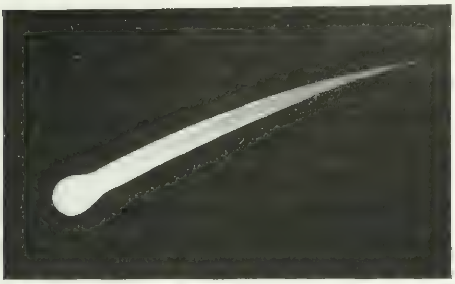


FIG. 7.—A BRIGHT FIRE-BALL SEEN OCT. 7TH, 1867.

find many varieties of orbit and origin. There may be terrestrial meteor rings that have an analogy with the zodiacal light. The planets Jupiter and Uranus have each their families of comets, and it is possible that the earth is attended by a number of the same bodies, the scattered and attenuated nature of which places them beyond the range of visibility. Evidently, we have much to learn about these shooting stars and about their allied comets; and he is wise who works and waits, without a too hasty assumption of knowledge that we do not possess, or a too ready broaching of theories based on insufficient materials.

The dates upon which the earth encounters the two great meteor showers of November—the Leonids and the Andromedes—have undergone a slow, progressive change. The Leonid shower on the first recorded occasion upon which it was observed fell on October 12th, 1902; its date of maximum now is November 15th. The Andromedes, on the other hand, meet the earth earlier as time goes on, and their chief date has moved backward in the year from December to November 23rd. The Leonid stream and its attendant comet are members of the family of comets connected with the planet Uranus. Their orbit is inclined at a high angle to the plane in which the planets of the solar system move, and cuts it in two points, which are also very nearly the points of its nearest approach to the sun and its greatest recession from it. At the first point it intersects the orbit of the earth, near the second it intersects the orbit of Uranus; but it passes far above or far below the orbits of the planets which lie between. These planets have not, however, been without their influence on the meteor stream; it is their attraction, and especially the attraction of Jupiter, the greatest of them, which has brought about that gradual movement of the whole orbit which has thrown the date at which the earth meets them later and later in the year. Calculating backwards the position of the stream, Le Verrier found that in the year 126 A.D. it was close to the planet Uranus, and he concluded that it had been moving prior to that time in an orbit which would have taken it to an immense distance from the sun—if, indeed, it had ever returned to it. The attraction of Uranus, however, changed this extremely extended orbit into a much narrower one, so that since that date the stream has been confined within limits which extend but very little beyond the path of Uranus. Proctor, however, disputed the possibility of a planet thus "capturing" a comet or meteor stream, and so compelling it to become a permanent member of the solar system, and he inclined to think that it took its origin in some mighty explosion on the planet Uranus, which flung it out to pursue an independent existence.

Sir Robert Ball has urged that the source of aërolites—meteors, that is to say, that actually reach the ground—should be sought in our own earth itself, and that

they were ejected from it in long past ages, when it was in a different condition from what it is now. He draws a distinction between aërolites and the meteors of such showers as the Leonids and Perseids. The latter, moving with great velocities relative to that of the earth in virtue of their cosmical origin, are vaporised in our atmosphere, and never reach the ground in a concrete form. But the aërolites, if originally ejected from the earth, as his theory suggests, would move round the sun in elliptic orbits which would cut that of the earth at the point where the explosion originally took place; and when, after very many revolutions in their respective orbits, the two bodies meet again at the point of intersection, and with no very great relative velocity, the earth receives again its lost fragment, which may reach the ground, if it be large enough, without being entirely burnt up. But the late Prof. H. A. Newton investigated the orbits of those aërolites for the determination of which we have sufficient data, and found that about 90 per cent. of these were moving around the sun before their encounter with the earth in paths which were not parabolic, but resembling those of short-period comets or the more eccentric asteroids, and nearly all direct; thus suggesting a planetary rather than a stellar origin. Prof. Young suggests that they may be possibly minute outriders of the asteroid family.

FIG. 8.—FIRE-BALL OF NOV. 23RD, 1877.

It was long known, before the fact of a connection with comets was ascertained, that shooting stars moved with planetary velocity, and that their average height above the earth's surface was less than 100 miles. The same meteors were occasionally observed at two different stations, and the paths, when compared, showed a large displacement or parallax, and the amount of this afforded a ready means of calculating the meteor's height above the earth, the actual distance (forming the base line) separating the two observers being known. Brandes found, as early as 1823, that of 100 shooting stars seen, 22 had an elevation of between 24 and 40 miles, 35 between 40 and 50 miles, and 13 between 70 and 80 miles. Of 66 shooting stars recorded in August, 1863–71, Prof. Herschel determined the average heights as 78 miles at first appearance, and 53 miles at disappearance, giving an elevation of $65\frac{1}{2}$ miles at mid course. The velocity of a similar number of meteors, he found, had an average of $34\frac{1}{2}$ miles per second. Heis's work, embracing a summary and analysis of 43 years' observation, gives the heights of 262 shooting stars. The largest number first became visible at 67 miles, and disappeared at 44 miles. The several results show differences, but it must be remembered that these bodies vary a good deal in their heights and velocities. The latter element depends upon the position of the meteor orbit with respect to the earth at the time of intersection. If the meteors are coming directly from that point towards which the earth is moving in her orbit, it is evident that they will be of extreme swiftness, because their orbital speed is increased by the earth's, which corresponds to $18\frac{1}{2}$ miles per second. The Leonids of November nearly fulfil this condition, and their calculated speed is

FIG. 9.—FIRE-BALL SEEN AT CHELMSFORD, SEPT. 5TH, 1875.

44 miles a second. On the other hand, meteors coming from a stream pursuing a similar course to the earth will be characterised by slowness of motion, because they have to overtake the earth, and their orbital velocity is lessened by the amount of the earth's velocity to the extent before mentioned. The Andromedes (or meteors of Biela's comet), visible on November 27th, partake of the latter class; hence their calculated speed is only 12 miles per second. Thus it is evident that the apparent velocities of shooting stars depend in great measure upon the angles at which they meet the earth.

Photo kindly supplied by C. P. Butler, Esq.

FIG. 10.—AN EXPLODING METEOR.

It is difficult to select, from amongst the large numbers of known meteor systems, those which afford the most conspicuous displays, but it is believed that the following short table comprises many of them. The positions are given in right ascension and declination.

Jan. 2—3 . .	230 + 53°	July 28 . . .	339° — 11°
Jan. 17 . . .	295 + 53	Aug. 4 . . .	30 + 36
Feb. 1—4 . .	211 + 60	Aug. 10—12 .	45 + 57
Feb. 15 . .	230 + 11	Aug. 21—25 .	291 + 60
Feb. 20 . . .	181 + 34	Aug. 25 . . .	5 + 11
Mar. 4—15 .	175 + 10	Aug.—Sep. .	340 + 0
Mar. 24 . .	161 + 58	Sep. 10—22 .	74 + 42
April 17—24 .	241 + 47	Oct. 18—20 .	92 + 15
April 19—21 .	270 + 33	Oct. 29 . . .	109 + 23
May 6 . . .	338 — 2	Nov. 2 . . .	55 + 9
May 30 . . .	333 + 27	Nov. 14—16 .	150 + 22
June 13 . . .	310 + 61	Nov. 20—23 .	63 + 23
June 20 . . .	335 + 57	Nov. 23—24 .	25 + 43
July 4 . . .	303 + 24	Dec. 6 . . .	80 + 23
July 25—Sep. 15	48 + 43	Dec. 10—12 .	108 + 33

As to the number of meteors a person may expect to see on ordinary nights, Schmidt, of Athens, sets the average number at 14 per hour. Mr. W. F. Denning, of Bristol, by far the most experienced of meteor observers, gives an average of 10 per hour in the evenings and nearly 17 in the mornings, from observations of 3,323 shooting stars during the last six months of the years 1876–78. For the first half of the year the figures would be somewhat less. The average hourly number in the morning is much greater than the hourly number in the evening, and the meteors move much more swiftly, since in the morning we are on the *front* of the earth as regards its orbital motion, while in the evening we are in the rear; and the earth's orbital motion is always directed towards a point on the ecliptic about 90° west of the sun. In the evening, therefore, we see only such meteors as overtake us; in the morning we see all that we either meet or overtake. The proportion of morning and evening meteors is just about what it would be if they came to us indiscriminately from all directions and with the parabolic velocity of 26 miles a second. Prof. Newton has estimated that the total number of meteors visible to the naked eye which enter our atmosphere daily must be between 10 and 20 millions, the average distance between them being over 200 miles. If we take in those smaller ones, which are only visible in the telescope, Dr. See increases the number to at least 100 millions daily.

The same systems supply large and small meteors. Fire-balls (of which examples are given in Figs. 7, 8, and 9)

intersperse with the most minute of these objects. As to their actual size little can be ascertained with certainty. The fire-ball of November 23rd, 1877 (Fig. 8), was estimated to have an apparent diameter of half a mile, but the solid nucleus must have had vastly smaller dimensions. The ordinary shooting stars are extremely small, and are conspicuous more by their light than their size. Observations, a few years ago, placed the weight of 20 of these bodies as varying between 30 grains and $7\frac{1}{2}$ pounds ; but there is no means of determining the mass of a meteor except by the light it gives out, and as an average meteor and a good electric lamp do not differ widely in their luminous efficiency it is probable that the ordinary shooting star weighs only a fraction of an ounce. If we assume the average weight to be a quarter of an ounce, then, on the basis of twenty million such bodies reaching the earth daily, the yearly increase of the earth's mass due to this cause would be 50,000 tons.

The number of small meteors also vastly exceeds those of great brilliancy. In the catalogues of meteor observers they are classed according to their brightness, as compared with star magnitudes. Mr. Denning, in order to determine the relative percentage of the various magnitudes of meteors, sorted out more than 50,000 shooting stars in various lists, and found that the best observations showed the following average proportions :—

Exceeding 1st magnitude.	Equal 1st mag.	2nd mag.	3rd mag.	4th mag. and below.
3·0	10·6	18·4	26·2	41·8

The results indicate a progressive increase of $7\frac{3}{4}$ per cent.

It is often asked, What becomes of the vast number of falling stars which enter our atmosphere ? It is impossible to conceive that they are utterly dissipated and vaporised in the upper regions. The probability is that after combustion they are frittered into dust, which slowly subsides upon the earth's crust ; for it has been shown that, though many of the particles of dust that are always floating in the air rise from the soil, some display a peculiarity of composition and form strongly suggestive of a celestial origin. A fall of "cosmical dust" has been inferred from the investigations of several scientists, whose conclusions appear to be that iron is mingled with the dust that has been accumulated in church towers by the winds of ages, and that this iron, as it floats in the air, is often trapped in its fall by snow, which frequently gives traces of it. In 1875 and 1876 a quantity of dust was collected from the towers of cathedrals and other elevated positions, and placed under chemical and microscopical analysis. The application of a magnet proved it to contain minute spherical corpuscles, with a slight roughness, which made many of them bottle-shaped. Snow was also collected at many places in France, and by Nordenskjöld in the arctic regions, care being taken to avoid the lower and upper layers. The presence of iron was detected in each of the residues, and there were irregular particles which were influenced by the magnet. A continuous fall of cosmical dust of meteoric origin seems to be suggested by these facts. But, though we have seen that on the basis of 20 millions of meteors per day, each weighing about a quarter of an ounce, 50,000 tons would be added to the earth's mass each year, Prof. Young calculates that, if the specific gravity of the average meteorite were equal to that of granite, it would take 800 million years for a layer one inch thick to accumulate over the earth's surface. The dust in the church towers and the snow may be partly meteoric, but the great proportion of it is far more likely to be due to fine volcanic dust, such as the great eruptions of Krakatoa or Soufrière, or Mont Pelée gave—if, indeed, it has not some more commonplace origin.

COLOUR PRINTING.

THE "THREE-COLOUR PROCESS."

By EDWIN BALE, R.I.

IN few departments of industry have such radical changes taken place during the last quarter of a century as in that of the illustration of works of literature. Twenty years ago steel engraving, wood engraving, and lithography were the chief methods in vogue; to-day the first does not exist so far as commercial illustrating is concerned, the second is almost a past art, and the third is gravely threatened, and has already had to surrender many of its fields of operation to the as yet imperfect "three-colour process." It is the advent and development of photography to which these changes are due, for although in the first instance photography came to the help of the wood engraver and printed for him on the wood block the subject he had to engrave, it was not long before the subject was not only printed upon a block of metal, but the block itself was engraved in a few minutes without the aid of the hand engraver, and at a cost very much below that of a hand engraving. What is now commonly known as a "process" block was the result. This is the block which, taking the place of an engraved wood block, is used to illustrate the magazines and other publications that are so constantly before us. Its invention has practically killed wood engraving, and it has virtually handed over the whole field of illustration to the process block maker. As it not only gives us the black and white illustrations which we know so well, with their delicate criss-cross lines and dots, but is the basis of the "three-colour process" also, it is necessary to explain, before we go any farther, what a process block is and how it is made, for without such an explanation it is hardly possible to make clear the methods and results of the "three-colour process."

There are two kinds of process block: one reproduces drawings that are made in lines entirely, and this is called a *line process* block; the other reproduces the tones and the variations of light and shade, of black and white, such as are exhibited by a photograph or toned drawing. It is this latter, the *tone process block*, which is of interest in connection with three-colour work and which has here to be described.

The early blocks, those which were first made, were very coarse in texture, and the criss-cross lines were wide apart and gave the picture the appearance of being looked at through gauze or fine net. Indeed, in early experiments this material was used for the purpose of forming the screen or grating which should break up the picture into dots, so as to get a surface that could be printed from.

But it may be asked, Why are these criss-cross or grating lines necessary? Why cannot the picture be printed to look as the photograph, in which no such lines appear? It is an interesting question, and here is the answer:—Suppose the plate of metal to be to hand, and the photograph printed on it. You want to be able to transfer that print to your sheet of paper. But to transfer anything from the metal plate, printer's ink or some printing substance must be rolled over the plate. But a roller will leave its ink deposit upon every part of the plate it touches, and in the case of a flat plate, although a charming photograph

COLOUR-PRINTING: THE "THREE-COLOUR PROCESS."

may be on it, will touch every part of the plate, and when this is impressed upon paper the result will be a black blot the same size and shape as the plate, with no suggestion of the picture. Now if that flat surface can be broken up into dots which come very close together in the places where dark shades are wanted, and which thin out in the lighter passages and altogether disappear in the portions which should tell as white, it will be readily seen that when the ink roller passes over this surface it will leave much ink where the dots are close together, none where there are no dots, and that between these two extremes every variety of tone from dark to light may give all the varieties of the photograph, but in a coarser way. When this surface is impressed upon the paper, the result will be all the gradations of black and white which go to make up the picture.

The "screen" which is now used to

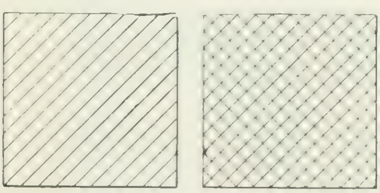


FIG. 1.—SHOWING ARRANGEMENT OF LINES ON SINGLE AND DOUBLE SCREENS.

break up the surface is made of two sheets of glass, as flat and clear and flawless as it is possible to get them. Each is engraved diagonally (Fig. 1), and into the engraved lines an opaque pigment, impervious to light, is rubbed. Much of the development of the process block is due to the improved method of engraving these screens. An automatic engraving machine has been invented by which it is quite easy to get from 200 to 300 lines to the inch engraved with mathematical precision. This means that it has become possible to produce blocks of a much finer grain than formerly—indeed, such fine grains are possible that the cross lines become almost invisible to the naked eye.

A B

FIG. 2.—FACSIMILE REPRODUCTIONS OF PORTIONS OF ACTUAL ENGRAVED SCREENS.

The two sheets of glass are placed with their engraved surfaces in contact, and are held together by Canada balsam. Fig. 2 shows (A) the single line glass and (B) the two glasses fastened together.

And now, with our sheet of metal—zinc or copper—and our glass screen, we are ready to make our process block, and this is how it is made :—

The subject to be reproduced with the cross-lined screen is exposed in front of the camera. At the back of the camera are the negative and the cross-lined screen, the latter about a quarter of an inch in front of the former (Fig. 3). A negative of the subject, as far as the negative can record it, is then taken, but it cannot record what is shut out by the lines of the screen, for they are filled by an opaque substance. It only records what is visible through the little squares of clear glass. The result is called a *screen negative*, and gives the subject with the lines of the screen all over it, crossing it diagonally at right angles.

The metal plate upon which this negative is to be printed is coated with a thin film of fish glue and bichromate of potash,

which is sensitive to, and hardens under, the influence of light.

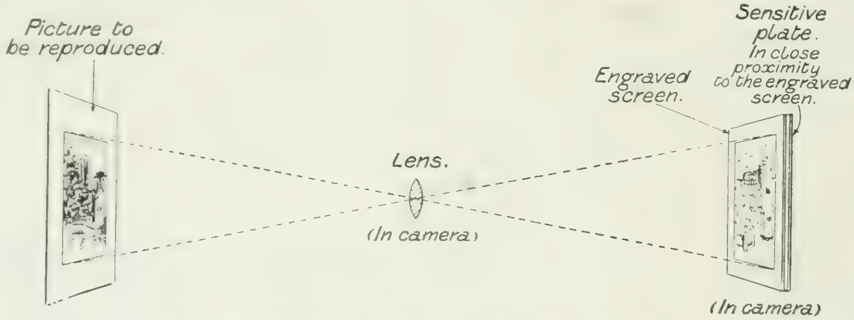


FIG. 3.—SHOWING THE RELATIVE POSITIONS OF THE PICTURE, LENS, ENGRAVED SCREEN, AND SENSITIVE PLATE.

The screen negative is laid upon the sensitive plate, which is exposed to light like an ordinary negative in process of printing. Where the light passes freely through the negative to the sensitive film the latter becomes quite hard. Where the light cannot pass, owing to the density of the negative, it remains quite soft; and between these two extremes there are the varying degrees of density and consequent degrees of hardness.

When the printing of the negative is completed, the metal plate is submitted to the action of water, and all the soft parts of the sensitive film are washed away, leaving the surface of the plate quite exposed in parts, quite covered and protected in others, and only partially covered and protected in others.

In this condition the plate is submitted to a heating process, and the whole of the film remaining on it is burnt or enamelled on to the surface of the plate. This burnt-on film now plays a very important part, for it protects the plate against the action of acid. The plate is next placed in a bath of corrosive acid, which eats down into it wherever the surface is

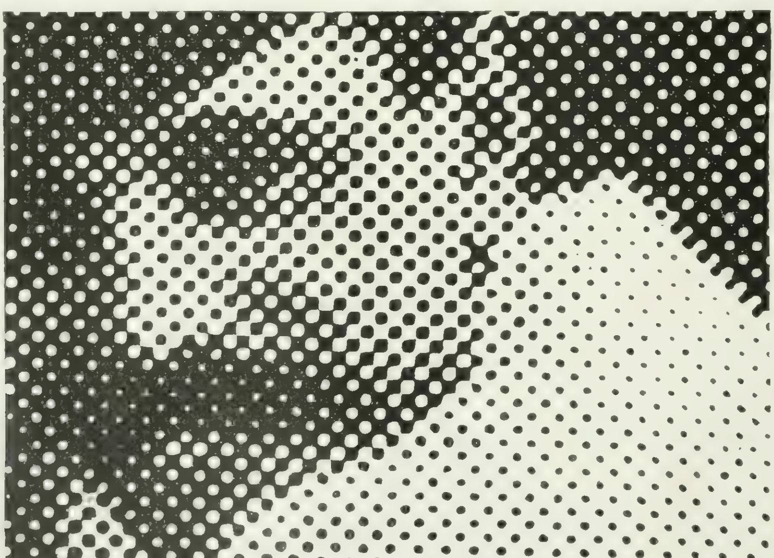


FIG. 4.—A MAN'S HEAD, REPRODUCED FROM THE SCREEN NEGATIVE.
Enlarged 15 diameters. Hold at arm's length to see effect.

unprotected, but leaves untouched the protected parts, which are the dots. These stand up and, in their varying relations, close together and wide apart, give the printing surface. Fig. 4 is a magnified view of a portion of such surface printed. Fig. 5 shows the surface of the block itself, with its upstanding points and etched out hollows. The plate is finally mounted upon a wood or metal block which makes it the same height as the type it is to stand with; and that is the story, simply told, of the process block which is used to illustrate our modern books and magazines.

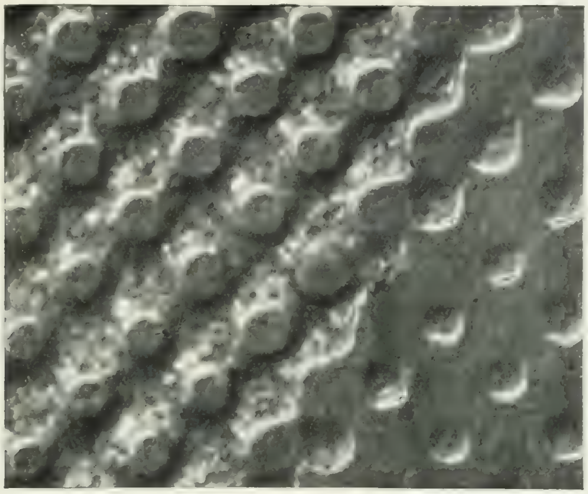


FIG. 5.—SURFACE (MAGNIFIED 40 DIAMETERS) OF AN ENGRAVED PLATE, SHOWING HOW THE METAL HAS BEEN ETCHED AWAY.

The relation of this block to the process of colour reproduction by means of three printings can only be understood by giving consideration to certain facts which are the outcome of the theory of colour.

It is an old theory that out of the three primary colours—blue, red, and yellow—all other colours and tones of colour can be obtained if only they are blended in right proportions (Fig. 6). They are called primary colours because they cannot be made out of a combination of others. Blue, red, and yellow are what may be called *foundation* colours. But very few pigments which are called by these names are actually pure. Whether blue, red, or yellow, they are mostly found with a slight admixture of one or both of the other primary colours. For example, crimson lake, a brilliant red, is not a pure red, but has blue in its composition; while vermilion, another brilliant red, has in it a proportion of yellow. And the same holds good with the blue and yellow pigments. But the theory of the three primary colours is based on the assumption that absolutely pure pigments are a possibility.

The first step in the combination of the primary colours is to mix two of them together and produce what is known as a *secondary* colour, of which there are three—viz. green, a combination of blue and yellow; orange, a mixture of red and yellow; and purple, which results from mixing blue and red. These secondary colours, of course, vary very much, according to the proportion of primary colours employed in their combination. Any mixture of blue and yellow will

produce green, but it may be a blue green or a yellow green, and infinite tints of green may be produced, from that which is almost blue to the opposite limit, where it may be almost yellow. So it is also with purple and orange.

The mixture of all these three "primaries," blue, red, and yellow, produces a *tertiary* colour, or grey, of which there are also three—viz. russet, olive, and citrine. In russet the red, as its name implies, dominates the other two; in olive the blue is the predominating pigment; while in citrine it is the yellow. Again, in the tertiary colours the utmost variety may be obtained, according to the proportions of the primary colours entering into their composition. It will from this be seen that, given the three primary colours, a proper blending of them may yield the whole colour range of the universe, passing from pure white, which is the absence of all colour, down through the "primaries" and "secondaries" to the infinite range of greys to be found in the "tertiaries." The three primary colours when printed solidly one on the top of the other should produce a good (simple) black.

It should be mentioned that this theory of colour applies to pigments only, and not to colour in light. The prism which has the faculty of separating the rays of white light into their component colours shows that white light is made up of rays of these same primary colours; but it is the presence of all three which gives white light, whereas with pigments the combination of the three produces black. It must be borne in mind that, when speaking of the theory of colours, pigmental colour is always referred to in connection with the "three-colour process."

"*Primaries.*"	"*Secondaries.*"		"*Tertiaries.*"			
BLUE.	BLUE RED	PURPLE.	*BLUE* RED YELLOW	OLIVE.		
RED.	RED YELLOW	ORANGE.	*RED* BLUE YELLOW	RUSSET.	*BLUE* *RED* *YELLOW*	BLACK.
YELLOW.	BLUE YELLOW	GREEN.	*YELLOW* RED BLUE	CITRINE.		

FIG. 6.—THE THEORY OF COLOUR: SHOWING THE RELATION OF THE "PRIMARIES" TO THE "SECONDARIES" AND "TERTIARIES."

The "process" is in its nature photographic and mechanical, and the theory of it is that, taking any coloured object—a flower, a carpet, or a picture—the colour of it can be analysed, so that, no matter how complicated the colours may be, they can be separated, taken out, and a definite record made of the three primary colours in the exact proportions in which they exist in the object itself; that having obtained this record, we can by means of metal blocks and the printing press put these colours together again in these same proportions, and so reproduce on paper the exact combination of *primary*, *secondary*, and *tertiary* colours of the object itself. This is the theory.

As a matter of fact, owing to the intractability of sensitive plates, the uncertainty of colour filters, the imperfection of the pigments of which printers' ink is composed, the defects and uncertainties of paper and machinery, and the lack of artistic training in fine etchers and printers who have to deal with the work, the practice falls far short of the theory. Nevertheless, the

results obtained are little short of miraculous; and, as time provides experience and education in all directions, we may hope to see still more wonderful results than any that have yet been obtained. As far as it has gone, the "three-colour process" is the nearest approach that has as yet been made to photography in colours.

We come now to the final stage of the subject, in which it remains to show how, upon this theory, the three blocks are prepared which are to produce such marvellous results, and effect in three printings more than has been possible in the past by the many printings of the old process of lithography. It should be borne in mind, in comparing the two processes, that twenty was by no means a large number of stones to have to prepare for the production of a good result by "chromo-lithography."

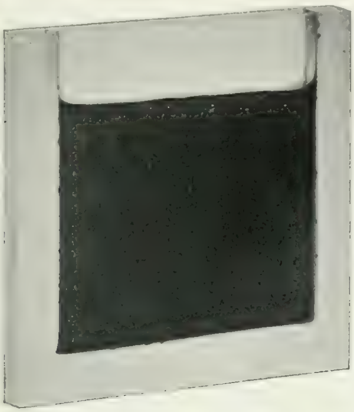


FIG. 7. A WET FILTER.

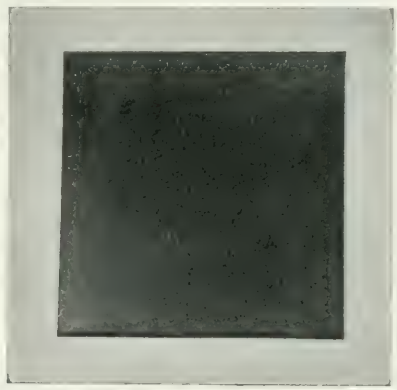


FIG. 8.—A DRY FILTER.

The first step in the process is the dissection or separation of the three colours, and obtaining photographic records of the blue, red, and yellow separately, as these enter into and make up the subject to be dealt with. It has been found that the rays of light reflected from coloured pigments can be filtered just as water can be filtered, and that, just as other substances than the water itself can be held back in a water filter and the pure water only allowed to pass, so, by a properly arranged colour filter, colours which exist and reflect their rays in combination can be controlled so that the rays of only one colour will pass through the filter at a time.

These filters are of two kinds—wet and dry. The wet filter is a cell or reservoir, its sides being made of two sheets of clear, flat glass, between which a dye of aniline colour is held in solution (Fig. 7). The same dye mixed with a solution of gelatine or collodion may be spread upon a piece of clear glass and allowed to dry, when another piece of glass may be fixed over the dye to protect it, and the two fastened together with Canada balsam. This will be a dry filter (Fig. 8). A different dye has to be used for the filtration of each colour.

For the Blue Printing Negative	Cochineal Red. Brilliant Yellow.
,, Red ,, ,,	Brilliant Green. Brilliant Yellow.
,, Yellow ,, ,,	Naphthol Green. Methyl Violet.

The filters properly prepared, they are placed one at a time in front of or behind the lens of the camera while the object is being photographed on to a specially sensitive negative. If the negative looked for is to be a record of the blue rays of

FIG. 9.—A PRINT FROM THE BLUE PLATE.

the object, that one of the filters enumerated will be used, which will keep back red and yellow and permit only the blue to pass to the negative, which consequently will record the values only of the blue tones of the object. So with the red and the yellow. These negatives can then be used as any ordinary negative, prints taken from them, and process blocks made in the way already described.

In the page of colour which illustrates this paper (*see* Frontispiece), prints of the three blocks which go to produce the finished result are given separately, printed each in its own colour; but it is a matter of considerable interest, as showing the different results obtained by the three negatives, to show what they are like and how they compare when printed in the same colour. They are therefore here printed side by side in black, so that comparison of them may be made (Figs. 9, 10, and 11). Observe how strong the blue block is in those passages like the sky, where the blue is to tell, and how faint by comparison in those passages of orange, such as the hair, and the orange mass between

FIG. 11.—A PRINT FROM THE YELLOW PLATE.

the shoulder and the knees; but both the red block and the yellow in these passages are very strong, and by their approach to blackness indicate that the two colours will be printed almost in their full strength. The red is absent from the green of the drapery, and neither red nor blue is to be found in the yellow disc of the moon. It will be of interest to compare the colour printing with these black blocks, and to note the change that comes about when the block is printed in its own colour. It is also of great interest to see the growth of the final result from its first simple

FIG. 10.—A PRINT FROM THE RED PLATE.

yellow printing through the second stage, where the red and yellow are together, to the final imposition of the blue by which the combination of colour is completed.

A very simple subject has been chosen for the purpose of these illustrations, the simplicity of the tones making investigation and comparison easier than would be the case were the subject more complicated.

It will be seen how simple is the theory of the process. It is a case of separating the colours of an object by means of a light filter into their component *primary* colours, and, finally, putting them together again upon paper by printing these three "primaries" one over the other. But, simple as is the theory, the practice is full of difficulty. "Three-colour work" is only in its infancy; the filtering of the colours is as yet very imperfect, and much work has to be done by hand to compensate for faulty photographic records. This will not always be, for the photographer is always at work on the problems with which such subjects bring him face to face, and as time goes on we shall know more of the action of the colours themselves, and how to separate them and record them with greater accuracy.

But side by side with these improvements must proceed improvements in printing and machinery processes and materials, and in the education of printers, photographers, fine etchers, and all concerned.

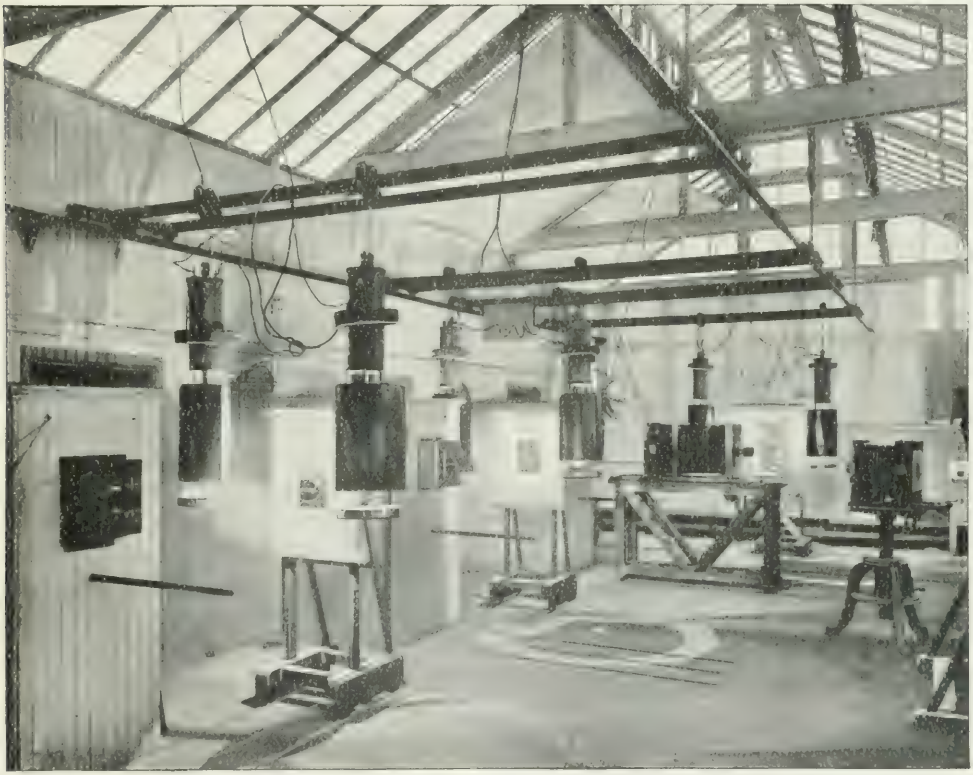


FIG. 12. PHOTOGRAPHIC ROOM FOR THREE-COLOUR WORK
By permission of Messrs. André & Sleigh, Bushey, Herts.

THE WIZARD ELECTRICITY.—I.

A WORKING DYNAMO AND THE PRINCIPLES WHICH GOVERN IT.

By FRANK C. WEEDON.

THE applications of electricity are numerous and complicated, and it is a life's work to master the details and keep abreast of the times even in some of the many branches of our subject. Yet it is by no means a hopeless task for the ordinary person to obtain an intelligent appreciation of the great scientific discoveries upon which are based the myriad modern developments of applied electricity. With these fundamental facts the present article will deal; in papers which will follow, their application to electric lighting and heating, electric tramways, telegraph and telephone systems, will be dealt with.

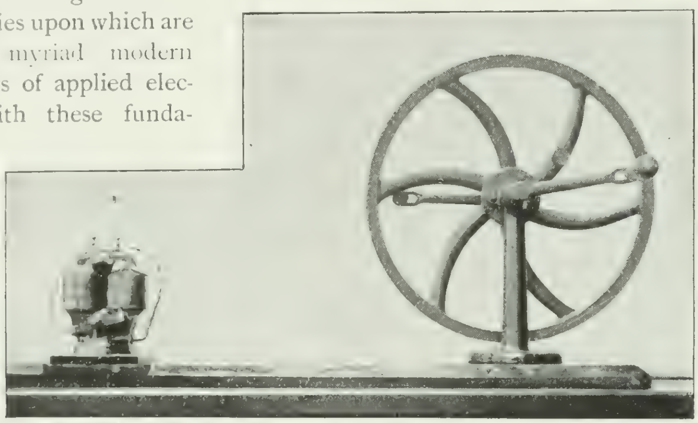


Photo: Supplied by F. C. Weedon.

FIG. I.—A SMALL DYNAMO DRIVEN BY A HAND-WHEEL.
The key rests against the field magnet.

A small dynamo of simple design makes an excellent starting point, and if the reader has access to any such machine, he will do well to make good use of his opportunity. For it may be remarked, in passing, that the knowledge of electrical science which can be obtained by reading alone is, as a rule, not worth having. This article will best achieve its purpose if it becomes a guide to the actual study of the phenomena described.

Turning to the dynamo (Figs. 1 and 2), we observe that it has two main parts, a horseshoe-shaped piece of iron, and a spindle, on both of which are wound loops of covered wire.

The spindle is made to revolve between limbs of the horseshoe, and when this is done we find that an electric current may be obtained. This can be shown by attaching a piece of wire to each of the two terminals of the dynamo and connecting the free ends of the wires with an incandescent lamp. Or in place of the lamp we may put an electric bell. In either case we observe two very important facts: the machine gives out a current only as long as the spindle is revolving, and while the current is flowing the horseshoe is a magnet. When the spindle stops, the magnetic properties of the horseshoe disappear. The second of these two observations may be made by bringing a piece of iron in proximity to the horseshoe. While the current flows it is strongly attracted, but the attraction will cease with the current.

Our attention is thus directed to two

considerations: the study of magnets, and the production of electric currents by the aid of magnets. To begin with the magnets. A small horseshoe magnet may be bought for a few pence. We find on experimenting that it has the power to attract pieces of iron or steel, but that it has no such power with such substances as wood, paper, and brass.

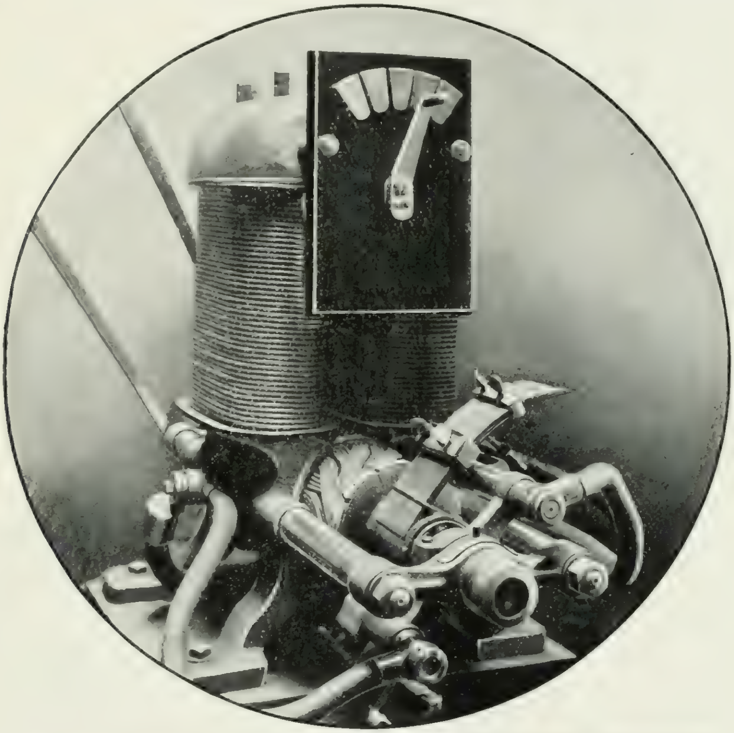


FIG. 2.—A LARGE DYNAMO USED IN THE ELECTROTYPING DEPARTMENT AT LA BELLE SAUVAGE.

It exhibits the same property when tested with cobalt or nickel, but practically we may say that iron and steel are the magnetic substances.

Pieces of steel which have been lying near the magnet, or stroked with it, are found to have become magnets themselves, and it is thus a simple matter to make a number of magnets for the purpose of experiment. Pieces of watch-spring or sewing needles answer admirably. Fix the piece of steel on a table with wax, and stroke it repeatedly with a magnet, always in the same direction. It is convenient to make several sewing-needle magnets simultaneously in this manner, arranging all the points at one end of the little bundle before beginning the process of magnetising.

Push one of these magnetic needles through a piece of cork and float it on water. Or, still better, thrust the needle through a small piece of paper and suspend it at the end of a fibre of cocoon silk. It will be found that the magnet possesses properties not existing in non-magnets—it tends to come to rest in a definite direction, which is nearly **N** and **S**.

If the needle is rotated out of this direction, it will, if permitted, return to it. Moreover, the two ends of the needle have distinct properties. If the needle is rotated through 180° it then is in the *direction* in which it tends to come to rest. But it will not remain so when released; it will naturally come to rest when one end, and that end only, is pointing to the **N**, and the other end pointing to the **S**.

If we put one of the needles on the table, and sprinkle over it some iron filings, we shall notice that the filings are attracted to both ends (Figs. 3 and 4). These two points to which the iron filings are attracted are called *poles*, and to distinguish them they are called *north-seeking pole* and *south-seeking pole* in accordance with the peculiarity already described. The abbreviations *north* and *south pole* are terms very often used in place of "north-seeking" and "south-seeking." If we present the north pole of one magnet to the south pole of another we observe that they mutually attract, but we find that two similar poles mutually repel. This is a fact of great importance, and may be expressed thus: *Similar poles mutually repel, and dissimilar poles mutually attract.*

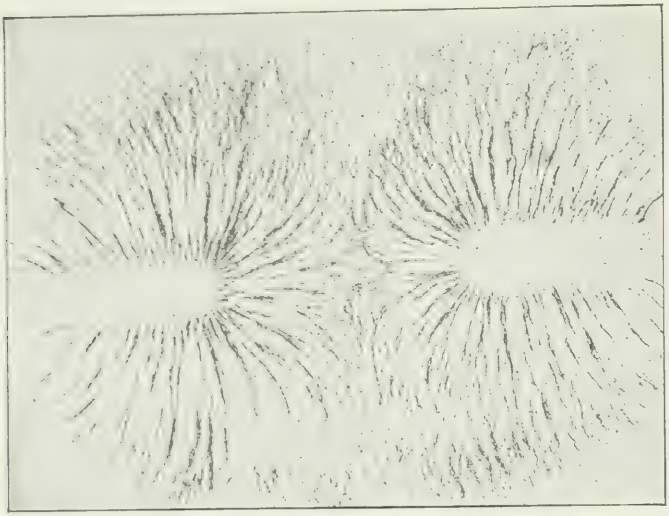


FIG. 3.—"SIMILAR POLES MUTUALLY REPEL."

Iron filings sprinkled upon a photographic plate lying on two magnets with their similar poles placed together will arrange themselves in this way.

The attraction and repulsion which takes place between two magnets *not actually in contact* leads us to the consideration of what is the essential part of our subject, viz. *magnetic fields.*

It is inconceivable that one magnet can affect another without there being some medium concerned in transmitting the influence. One may ring a bell in a tower by sending a strain along a rope, and this illustration has a general application. "Nothing can act except where it is," states one of the great laws of modern science. What, then, is the medium for the transmission of magnetic force? The accepted theory of to-day states that it is the same medium which transmits the energy of light, heat, and electricity. This same ether is without weight, is perfectly elastic, and fills all space.

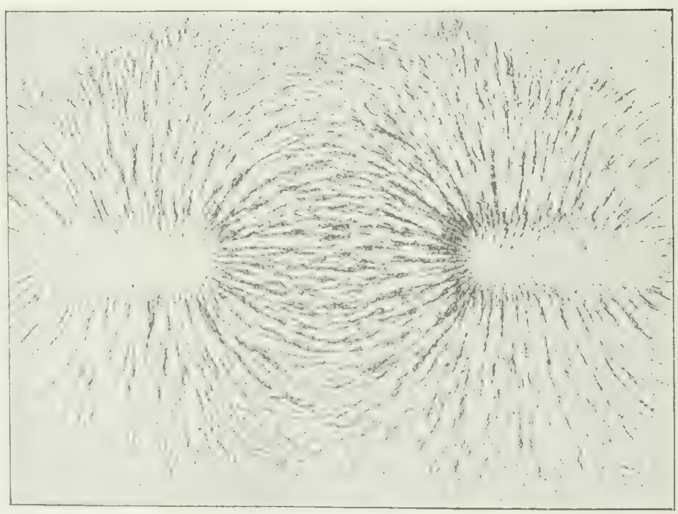


FIG. 4.—"DISSIMILAR POLES MUTUALLY ATTRACT."

Iron filings arrange themselves when the plate lies upon two magnets whose dissimilar poles are placed together.

If we twist or pull a piece of india-rubber, it will tend to revert to its original condition, and in so doing will exert force. The ether in the neighbourhood of a magnet is in a strained condition, and the magnetic force is found to act in definite directions. A well-known experiment will reveal much that is important at this stage. Put a sheet of smooth cardboard over a magnet and sprinkle iron filings over it. The iron filings should be fine, and should be "peppered" from a bottle with the mouth covered with muslin. The filings will be found to arrange themselves along well marked lines, showing the direction in which the force due to the magnet is acting. It is interesting and instructive to repeat this experiment, using several magnets arranged in various ways. The experiments show that for some distance around a magnet the magnetic force may be observed acting along *lines of force* roughly marked by the chains of iron filings. The region throughout which the magnetic force extends is called the *field of the magnet*, or the *magnetic field*. The lines are crowded towards the poles and are spread out in other parts of the fields, showing that the *intensity* of the field is greatest at the poles.

We have previously seen that if a piece of iron or steel is placed near a magnet it is magnetised, and the ideas we have obtained as to magnetic fields help us to an understanding of what the process of magnetisation really is. A piece of steel placed near a magnet, or stroked with a magnet, is traversed by the lines of magnetic force. This is what we always have to do to make a magnet; we must place the steel in a magnetic field. This always holds good, however much we may vary the actual process.

How, then, does it come about that if a piece of iron or steel is in a magnetic field it is magnetised? How does the magnetic force bring about the change? The lines of force are directions along which a magnetic pole is urged; so that if a short magnet is placed in a magnetic field its two poles tend to move along the lines of force in contrary directions. The result is, the magnet, as a whole, comes to rest along the line of force.

We are now in a position to follow the accepted theory—the *molecular theory of magnetisation*. Imagine a piece of iron divided into two, then one of these halves divided into two, one of these again divided, and the process continued. We can reach *in our imagination* a stage when further division is impossible. This particle of iron is called a *molecule*, and the molecular theory of magnetisation states that each molecule is a magnet, with, of course, both **N** and **S** poles. In a piece of unmagnetised iron or steel these molecular magnets are supposed to be arranged in groups so that the lines of force from one molecule run into the molecule or molecules near it and no lines pass out into the space around the piece of iron. When it is placed in a magnetic field the molecular magnets set along the lines of the field, and there are consequently, at the ends of the bar, poles which send out their lines of force to form an external field—or, in other words, the iron is magnetised.

It is more difficult to rotate the molecules of steel than those of soft iron, and it agrees with this that steel is comparatively difficult to magnetise, while soft iron acquires magnetic properties very readily, and loses them again with the same facility. The molecular theory affords an explanation of many phenomena which, until recently, were treated separately. We see that anything which agitates the molecules of a piece of steel is likely to change its magnetic condition. Any shock to a magnet will jostle its molecules, and it is to be expected that it will be weakened. We see also an advantage in keeping bar magnets side by side, with a piece of soft iron connecting their unlike poles. The lines of force run through the soft iron, along chains of its molecular magnets, and tend to prevent disarrangement of the end molecules of our bar magnets.

The fact that magnets will, if permitted, come to rest in a **N** and **S** direction shows that there is a magnetic field often unsuspected, viz. *the magnetic field of the earth.* This is comparatively weak ; otherwise we should have difficulty in obtaining a piece of unmagnetised iron. Still, it is sufficiently intense to magnetise iron and steel, but the process as a rule takes a long time. If an iron post or fire grate is tested, it will as a rule be found a magnet with its **N** pole at the bottom.

FIG. 5. OERSTED'S EXPERIMENT.
[illegible] the current is held in the same direction as the needle.

If the molecules of a piece of iron are agitated while in a magnetic field, it is to be expected that some will settle along the lines of the field, so that the magnetising process is assisted. We find, in fact, that a piece of iron, smartly struck, even when in so weak a field as that of the earth, is magnetised. When a substance is hot, its molecules are in a state of unusual vibration. We find, as we should expect, that heating a bar of iron or steel when in a magnetic field, makes a magnet of that bar.

There are magnetic fields identical with those we have already considered, except that they are not associated with a magnet of iron or steel. In 1819, Oersted of Copenhagen made the important discovery that a wire conveying an electric current is surrounded by a magnetic field. He showed that a magnetic needle tends to set itself at right angles to the wire carrying the current, and that the way the needle turns, whether to the right or left of its original direction, depends both upon the direction of the current and the relative positions of wire and needle. Oersted's experiment can easily be repeated by the reader. He will first have to produce the electric current. This can be done at a small expense by the following plan. Pour about a pint of boiling water on 3 ounces of potassium bichromate. When the solution is cold, add slowly, stirring the while with a glass rod, 2 ounces of sulphuric acid. Then add $\frac{1}{4}$ ounce of calomel.

A piece of thin sheet zinc should be bent so as to make a tube about 2 inches in diameter and a cork fitted in one end. Through the cork should be passed a stick of carbon, and a length of wire should be attached at one end to the carbon, and to the zinc at the other. The zinc tube should be dipped into the solution already described so that about $\frac{4}{5}$ of it is immersed. An electric current will then flow from the carbon to the zinc.

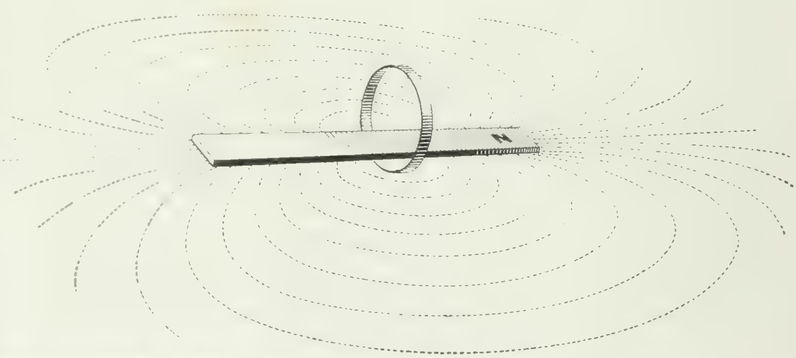


FIG. 6. LINES OF FORCE LINKED WITH A LOOP OF WIRE ENCIRCLING A MAGNET.

To perform Oersted's experiment (Fig. 5), the magnetic needle should be placed on a table and the wire conveying the current held near it, and in the same direction as

FIG. 7. THE ENGINE ROOM, HAMMERSMITH BOROUGH COUNCIL ELECTRIC LIGHT WORKS.

the needle. The effect should be noted in four cases—

(1) Wire above needle, and current flowing **N** to **S**.
(2) Wire above needle, and current flowing **S** to **N**.
(3) Wire beneath needle, and current flowing **S** to **N**.
(4) Wire beneath needle, and current flowing **N** to **S**.

The movements of the needle make it evident that there is a magnetic field near the wire when the current is flowing. The directions of the lines of force can be shown, as before, with iron filings. The experiment may be arranged as follows. Pass a fairly thick wire (B.W.G. 16 or 18) through a piece of stiff, glazed cardboard, and arrange that the wire shall be vertical several feet on both sides of the cardboard, which should be fixed horizontally. A strong current should then be sent along the wire, and iron filings peppered on the card. If the card is tapped gently the filings will arrange themselves, showing the lines of force, which are concentric circles round the wire.

If the wire is bent into a loop it is clear that there will be lines of force linked in with it at all points like those shown at two places in the drawing (Fig. 6). It is clear that there will be a magnetic field both within and around the loop, and that at the centre of the loop the direction of the magnetic force will be at right angles to the plane of the coil. If we wind the wire so as to make a spiral, we can increase the number of lines and so increase the intensity of the magnetic fields.

Or a spiral can be wound on a cardboard tube and the two ends of the wire connected with the carbon and zinc of the cell already described. The arrangement should be suspended by silk fibres so that the zinc plates are hanging in the exciting fluid.

It will be observed that the spiral behaves just like a magnet. It sets in a **N** and **S** direction, and its two ends are attracted and repelled by a magnet. It will be noted also that the spiral is only a magnet while the current is passing. If bare wire is used to make the spiral, the turns must not be allowed to touch, otherwise the current will flow across from

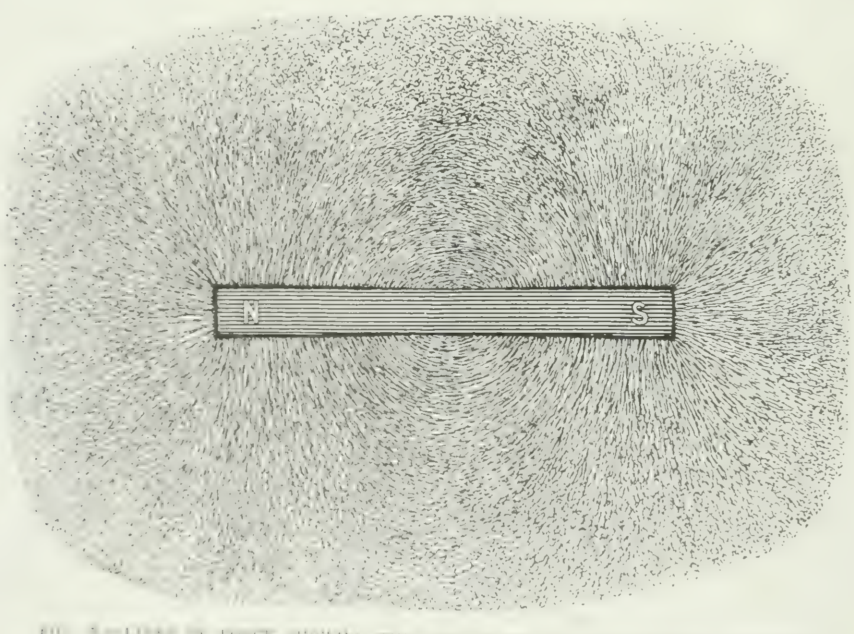


FIG. [illegible].—LINES OF FORCE SHOWING THE DIRECTIONS OF THE MAGNETIC STRESSES IN THE "FIELD" OF A SINGLE BAR MAGNET.

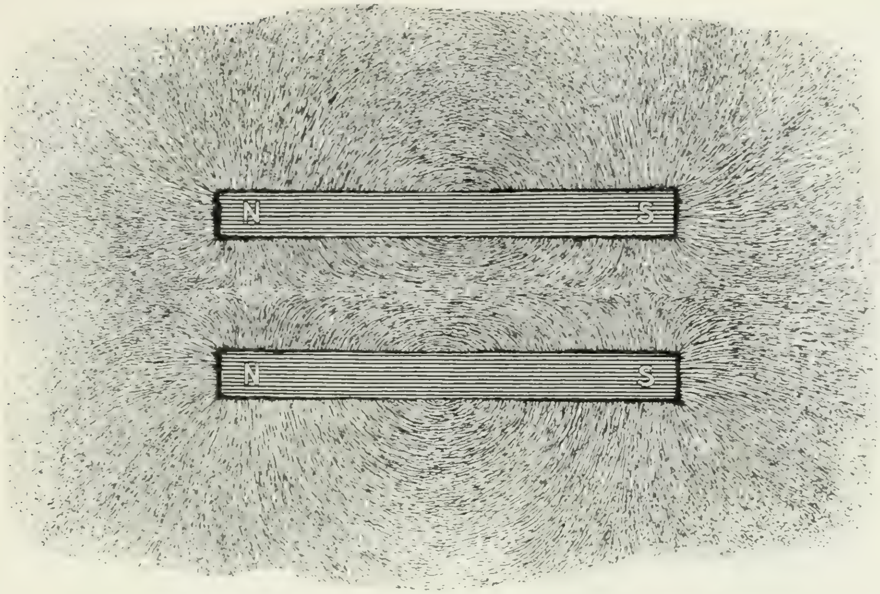


FIG. 9. LINES OF FORCE, SHOWING REPULSION OF "SIMILAR POLES."

one turn to the next. The most convenient plan to adopt is to use wire covered with a material which will prevent the current from flowing from one turn to another. Cotton-covered wire answers this purpose, and may be obtained at any electrical store.

Continuing the experiments on the magnetic properties of the current-carrying spiral, it will be found that the polarity depends on the direction of the current, and it does not matter at which end of the spiral the winding begins.

Remembering that a line of force is the direction along which a free magnetic **N** pole tends to move, the relation of magnetic force to electric current may be summed up in the rule of Clerk Maxwell: "The direction of the current and that of the resulting magnetic force are related to one another, as are the rotation and the forward travel of an ordinary corkscrew."

The formation of a magnetic field within a spiral carrying a current leads to the construction of an instrument for detecting the existence of an electric current. A coil of many turns of covered wire is made, and at its centre is suspended or pivoted a light magnetic needle. The coil may be placed so that its plane coincides with the length of the needle. If a current passes through the coil, the magnetic field within it will be perpendicular to the axis of the needle, which will accordingly move. An instrument made in this manner is called a *detector* or *galvanometer*. If a wire is suspected of carrying a current, it can be broken and the two ends joined to the ends of the spiral. A movement of the needle will indicate whether there is a current, and if so, what is its direction.

From what has been stated we can understand how magnets are made by the agency of electric currents (Fig. 11). The iron or steel is placed within a spiral, or solenoid, and a current is passed. While the current is flowing there is a magnetic field of which the lines of force act along the axis of the spiral.

If the experiment is made with very soft iron, it is found that a powerful magnet is made immediately the current is turned on, but that the magnetic properties disappear with the cessation of the current. Magnets of this kind are called *electro-magnets*.

We saw that the limbs of the horseshoe-shaped piece of iron in the dynamo with

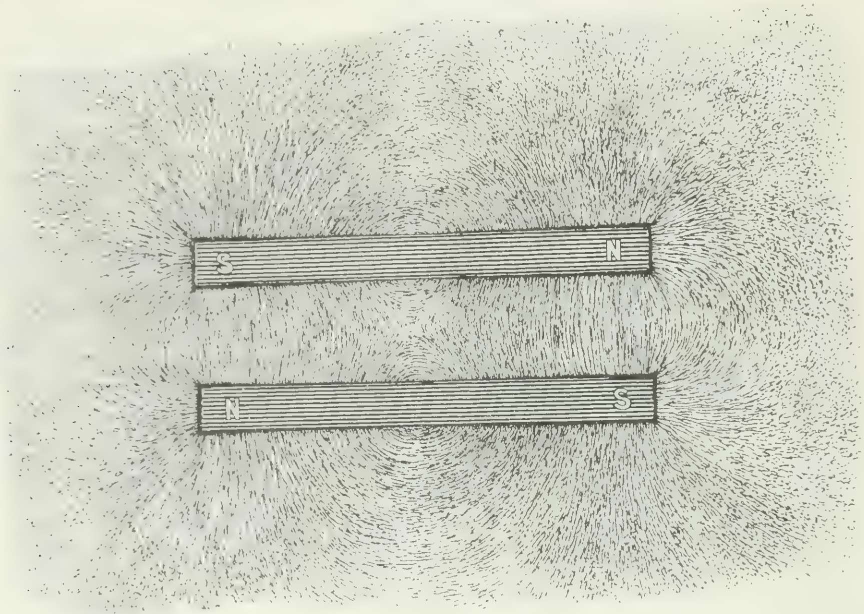


FIG. 10.—LINES OF FORCE: ATTRACTION BETWEEN "DISSIMILAR POLES."

which we began were wound round with covered wire, and we now understand how it was that it was a magnet only while the current was flowing. But how did that current arise? This brings us to a very important part of the subject—the production of electric currents by magnets. It is

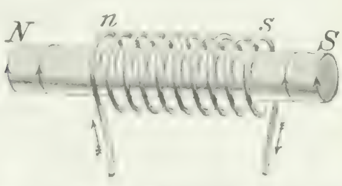


FIG. 11.—A SIMPLE ELECTRO-MAGNET, SHOWING HOW MAGNETISM IS OBTAINED FROM ELECTRICITY.

When an electric current is passed along the [illegible] in the direction denoted by the arrows, the [illegible] becomes a magnet with N and S poles.

to Michael Faraday that we owe this enormously important discovery.

Oersted had shown how to obtain magnetism from electricity, and Faraday was convinced that electricity could be obtained from magnetism (Fig. 12). His researches at first were failures, but eventually in 1831 he succeeded. The account of the experiment is given in the discoverer's own words: "A cylindrical bar magnet three-quarters of an inch in diameter and eight inches and a half in length had one end just

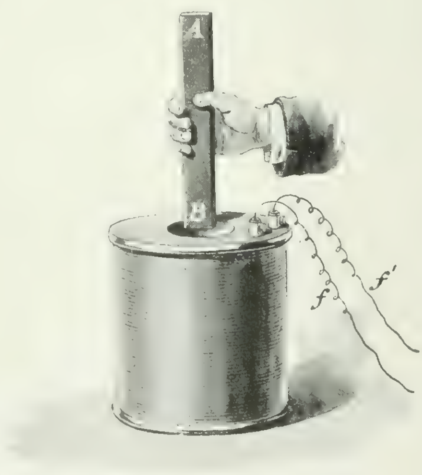


FIG. 12.—ELECTRICITY PRODUCED BY MAGNETISM.

A B is a magnet thrust into the hollow of a coil of wire. When this is done a current of electricity passes along the wire f f'.

inserted into the end of the helix cylinder, then it was quickly thrust in the whole length, and the galvanometer moved; then it was pulled out, and again the needle moved, but in the opposite direction.

This effect was repeated every time the magnet was put in or out."

The reader can without great difficulty repeat Faraday's celebrated experiment. The detector must be sensitive or there must be many turns in the spiral. It will be observed that the currents obtained are but transitory—just an electrical impulse along the wire and all is over until the magnet is moved. If the magnet is kept at rest and the spiral moved to or from it, the effects produced are the same as those obtained by moving the magnet to or from the stationary coil.

The experiment may, with advantage, be varied by replacing the magnet by a coil carrying a current. This coil, as we have seen, is to all intents and purposes a magnet while the current is flowing. So that we are quite prepared to find, as we do, that a current is produced as before in the original coil. To distinguish these coils, that coil which takes the place of the magnet in our experiments is called the *primary* coil, and the other in which the transient currents are produced is called the *secondary* coil. The current which is produced in the secondary coil is called an *induced* current. It will be observed from the directions of the deflections of the galvanometer needle that the induced current is always in the opposite direction to that in the primary. Instead of thrusting the primary towards the secondary, the two coils may be placed with their axes coincident. Then starting or stopping the current in the primary is the same as bringing it up very rapidly from infinity.

The nearer the two coils are the more powerful will be the effect, so that they are sometimes wound one over the other. If they are wound in this manner round a hollow cylinder, it will be found by experimenting that the results are greatly increased by placing within it a cylinder of soft iron, or, still better, a bundle of soft iron wires.

Let us now consider what happens when induced currents are produced, and for simplicity take the case of the bar magnet and the coil.

The lines of force of the magnet are loops, linked with the coil. When the magnet is moved, the number of loops linked with the coil is altered, and when this happens we obtain an induced current. This holds good always. If there is a conductor of electricity, and if by any means the number of lines of magnetic force passing through it *alters*, then a transient induced current will flow in the conductor. Decreasing the number of lines of force passing through the conductor produces an induced current in one direction, while increasing the number of lines passing through the conductor produces an induced current in a contrary direction. Thus it happens that if a loop of wire is rotated before the end of a magnet, currents are formed in the loop which *alternate* in direction.

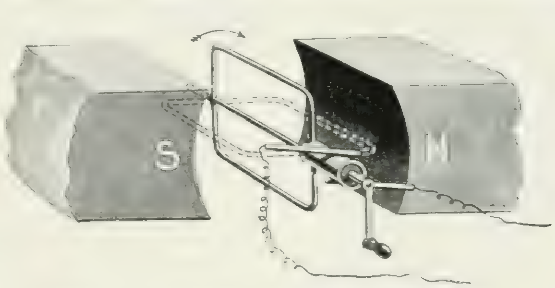


FIG. 13.—DIAGRAM OF SIEMENS' ARMATURE.

N. and S. are the dissimilar poles of two magnets between which a coil of wire is made to revolve.

In Siemens' armature, of which a diagram is shown at Fig. 13, a coil is made to revolve between the poles of two magnets by means of a handle. The ends of the coil are connected to two "half-sleeves" on the spindle. On these "half-sleeves" press two brass strips, known as "brushes," and these in their turn are connected with the wires of the outer circuit. The movements of the coil towards and away from the magnet poles

produce currents which change twice in direction during each revolution. These alternating currents pass to the two "half-sleeves," thence to the "brushes," and so to the wire which feeds the engine. *The current in the outside wire, however, does not alternate in direction*, for at the instant when the current in the coil changes in direction the "half-sleeves" change "brushes." Thus each brush receives the current in the same direction. An apparatus of this kind is called a *commutator.* It is obvious that some form of "commutator" is required in all electro-magnetic machines in order to turn these reversing currents in the same direction.

We have now mastered the main principles in the working of the dynamo. The horseshoe is at first a weak magnet. When the spindle revolves, each loop rotates in the magnet field and induced currents are formed. These currents are transitory, but if the loops are numerous and carefully placed on the spindle the transient currents succeed each other with great rapidity. The currents are conveyed by covered wire around the limbs of the horseshoe, thereby strengthening its magnetic powers. This in turn makes the induced currents more powerful, and so we have a cumulative effect which reaches its limit when the horseshoe or *field magnets* are *saturated.* We have seen the reason for the employment of soft iron for field magnets, we have learnt how electro-magnets are made, and we have studied the production of induced currents. This knowledge is the foundation of all modern applications of electrical science.

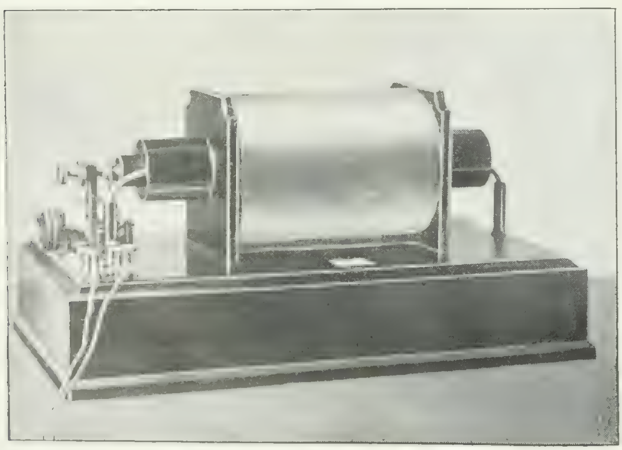


FIG. 14.—AN INDUCTION COIL.

This apparatus contains several miles of copper wire.

THE SLEEP OF PLANTS.

BY JOHN FRASER, F.L.S.

THAT sleep at regular intervals and for certain periods is necessary to the well-being of animals, man included, we all know. That plants, in their turn, need periods of repose, although equally appreciated by the botanist, is an item of nature knowledge in possession only of a few; perhaps it does not hold outside scientific circles. This position is the outcome, in a great measure, of regarding the animal and vegetable kingdoms as related, if at all, only in a minor degree, or, rather, of looking upon them as things apart and irretrievably separated.

Yet plants must sleep, as well as animals, and if the sleep of the former has in some respects rather a different significance than it has in the latter, yet the two have also many points of resemblance, or at least of analogy.

The owner of a garden or grounds well stocked with plants, if he is at all observant, cannot but have been charmed with the bright and open-faced appearance of everything on a clear morning, especially if it has rained over night or a heavy dew is lying on the plants. The cheerful appearance of everything may be maintained throughout the day; but if the observer lingers long after sundown, and the dews begin to fall, he is almost certain to be struck with the altered aspect of something he may have been looking at during the day. It may be that the foliage of the wistaria or of the false acacia is drooping, or that the clover, among the grass at his feet, has closed up as if parched with the heat of the day. The fact is that the leaves have gone to sleep, or assumed the night position.

So conspicuous a phenomenon could hardly escape notice; and, indeed, we have it on record that it was observed as early as the time of Pliny. Since Linnæus wrote his "*Somnus Plantarum*" these movements, popularly known as the sleep of plants, have been the subject of frequent and close investigation by the learned. By none, perhaps, has the subject been more extensively or brilliantly elucidated than by the immortal Darwin.

Complicated as are the sleep movements, or *nyctitropism*, of leaves, Darwin and other observers have shown that it is only one phase or phenomenon of the *circumnutation* of foliar organs, induced and regulated by the alternation of night and day, or light and darkness.

The most extensive movements of mature leaves occur in those which are furnished with a *pulvinus*, situated at the base of the stalk of simple leaves, and the leaflets and pinnæ of compound leaves. The pulvinus is a thickening or swelling, made up of small cells, and so constructed as to permit of movement. Popularly it is termed a joint. In the sensitive plant (*Mimosa pudica*) pulvini are present in all these parts, all of which twist round together, so that the movements are very complex indeed. In some plants the pulvinus is very feebly developed, while in the great majority it is entirely absent; yet some plants exhibit movements where no pulvinus is discernible, though they cannot, in the nature of things, be great.

The phenomena of sleep also depend upon certain conditions. Moisture must be adequate both at the roots of the plant and in the atmosphere; the temperature must be sufficiently high, and the leaves must have been well illuminated during the day, otherwise little or no inclination to sleep may be exhibited. These latter conditions are well illustrated towards the end of our summer, when the temperature sinks, and the skies become overcast and cloudy. The plants fail to sleep, or do so feebly,

even in hot-houses where the temperature is sufficiently high.

Many flowers close at night and open during the day, and are popularly said to sleep and wake, but their movements

FIG. 1.—THE DUTCH CLOVER (*TRIFOLIUM REPENS*).
(*a*) *The leaf when awake.* (*b*) *The leaf asleep.*

are due to changes of the temperature rather than light. Tulips belong to this class, but they may close at mid-day, or remain closed all day in cold, cloudy, and showery weather. The star of Bethlehem (*Ornithogalum umbellatum*) and the daisy (*Bellis perennis*) are other familiar examples.

The prevailing feature of plants that go to sleep is that the leaves or leaflets at nightfall place their apex, base, or edge, vertical to the zenith. The upper or under surface of the leaf may be exposed laterally, but frequently the former is more or less covered up, dependent upon the manner of folding or closing ; but no case seems to have been discovered where the upper surface is exposed to the zenith at night.

When leaves that possess the faculty of movement are about to assume the night position, they, or their leaflets, move either upwards, downwards, forwards, or backwards, often turning more or less on their axes in order to do so. No twisting takes place where the pulvinus is absent. Compound leaves generally possess several of these movements, as in the sensitive plant, the primary, secondary, and tertiary pulvini of which all operate simultaneously, though independently of one another.

For the convenience of studying the various forms of sleep movements to be met with among plants, it will be convenient to classify them under a few leading types or groups. In minute particulars the different movements and ultimate nocturnal position of leaves, pinnæ, or leaflets, defy classification, but it will be sufficient to indicate some of the more important variations from the adopted types.

The simplest form of sleep movement is that in which the leaf, or its *lamina* or blade, rises up vertically at night, as in the young leaves of *Stellaria*, *Nicotiana Tabacum*, and *N. glauca*, or the adult leaves of *Maranta arundinacea*. By this means the leaves form a crowded mass, greatly reducing the diameter of the plants and the area exposed to radiation at night.

A very common instance, but uncommon type, of sleep movement occurs in the Dutch or white clover (*Trifolium repens*, Fig. 1). At sundown, or soon after, the two lateral leaflets twist round upon their pulvinus, approaching one another face to face, and at the same time sinking downwards till they are at an angle of 45° with the main petiole. The terminal leaflet rises up vertically; then, turning over on its face, becomes slightly folded upon itself, forming a sort of saddle on the lateral ones, with its lower surface to the sky. It thus passes through an angle of 180°. The complete nocturnal position (Fig. 1, *b*) is very quickly assumed after sundown on a bright day, and may be observed long before darkness sets in. The folding of old leaves may be less complete, and, occasionally, the stems of grasses or other plants growing amongst the clover interfere with the closing movements. Other species behaving in a closely similar manner are *T. subterraneum* and *T. fragiferum*.

A remarkable appearance is presented by *Lespedeza juncea* (Figs. 2 and 3) when asleep. The slender, rush-like stems are erect and thickly clothed with leaves that

spread more or less horizontally when fully expanded. On the approach of nightfall the whole leaf rises up vertically, and the

FIG. 2.—*LESPEDEZA JUNCEA* BY DAY.

two lateral leaflets approach each other face to face, while the terminal one becomes slightly folded, with its mid-rib pressed against the edges of the lateral ones. With the exception of position, this is exactly the manner of folding met with in *Trifolium*, but the result is vastly different. The leaves being inserted all round the stem, they completely cover and hide it from view when asleep. The leafy stem of this plant may be compared to a fox's brush by day and a rat's tail by night. A strong breeze will also bring about the closing movement early in the afternoon, the object of closing in this instance being intended, apparently, to check loss of water by transpiration.

A slight modification of the above method of going to sleep occurs in several other genera. The short, stiff petiole of *Lotus creticus* remains horizontal, while the three leaflets and two stipules rise up vertically and face the stem, with their apices to the sky. The leaflets of *Medicago marina* are slightly more folded upon themselves, and bend more obliquely towards the axis; but otherwise the case differs little from *Lotus creticus*. The leaves of *Trifolium minus* have also short petioles, and the leaflets of the younger ones rise up vertically and press themselves against the axis, forming a large bud.

Among cryptogams, *Marsilea quadrifoliata* presents an interesting case. When awake, the four leaflets form, roughly, the quadrants of a circle. When going to sleep, the two uppermost leaflets rise up vertically and twist upon their pulvinus face to face, after which the two lateral ones follow suit and grasp the others between them.

A very common plan of sleep movement is that in which the leaflets of pinnate or bipinnate leaves turn vertically upon their edges, then moving forwards—that is, towards the apex of the primary or secondary mid-rib—close up face to face. Except the basal one, the lower half of each leaflet is covered by the one next below it, and all are imbricate like the slates on a roof. The tamarind (*Tamarindus indica*) is a good instance of a pinnate leaf which behaves in this way.

FIG. 3.—*LESPEDEZA JUNCEA*. *Leaves hugging the stem by night.*

Bipinnate leaves behaving in the above manner are very numerous, the leaflets closing up face to face against the secondary mid-rib, just as in the primary one of *Tamarindus*. The sensitive plant (*Mimosa pudica*, Figs. 4 and 5) is one of the best known instances. The leaves are so sensitive that they respond not only to the presence or absence of light, but to

mechanical, chemical, and electrical stimuli. With the first-named only are we at present concerned. From dawn till sundown the main petiole keeps sinking, the fall being very rapid towards evening, when the secondary petioles also sink and become directed forward, while the leaflets close up. This is the night position, the leaves being asleep. During the early hours of the night the primary petiole begins to rise, and continues till it forms an acute angle with the stem, while the mid-ribs of the pinnæ gradually spread out during the same period. After midnight the primary petiole begins gradually to sink till it assumes the usual position by day; and the leaflets are ready to wake with the dawn.

[illegible]

FIG. 4.—THE SENSITIVE PLANT (*MIMOSA PUDICA*).

The leaves are fully expanded by day, but if touched by the hand they close up and assume the same position as they do at night.

A very singular and interesting case of sleep movement occurs in *Coronilla varia* (Fig. 6). The leaves consist of six to eight pairs of leaflets, with an odd one. With the morning light these spread more or less horizontally on a straight or slightly arching mid-rib. Towards nightfall the leaflets begin to rise up vertically, and then become directed backwards, that is, towards the base of the leaf; while at the same time they approach one another, or come into contact face to face. The younger leaves exhibit the most perfect instance of the phenomenon. The leaflets do not overlap one another, owing to there being a relatively wide interval between every two pairs. The lowermost pair usually grasp the stem.

Hitherto we have been considering those cases in which leaves or their leaflets turn their apices or lateral edges to the zenith in assuming the nocturnal position, the terminal leaflet of *Trifolium* being a remarkable exception. We may now consider a few representatives of the large number that turn their basal edges to the zenith in carrying out their preparations for sleep. This the leaflets do by sinking or curving downwards or by becoming deflexed by various simple or complicated movements. The particular form of motion is very largely or entirely dependent upon their structure. Except where otherwise mentioned, it may be taken for granted that those to be considered belong to the pea family (*Leguminosæ*).

The wood sorrel, *Oxalis Acetosella* (*Geraniaceæ*, tribe *Oxalideæ*) represents a simple type of this group. During the day the three leaflets radiate horizontally from the apex of a common petiole or footstalk. At sundown, or earlier in shady situations, the leaflets gradually sink downwards till perfectly vertical, with their basal edges to the sky. When looked at

from above, in the night position, they form a triangular figure, somewhat folded upon themselves, and concave on the three faces. They are then back to back, with the common petiole in the centre position. This is the nocturnal condition. The leaves of the wood sorrel closely resemble those of the clover by day; but at night they look totally different. Many other species of *Oxalis* having three leaflets behave in a similar manner, but there are some exceptions. A remarkable case occurs in the telegraph plant (*Desmodium gyrans*). The pinnate leaves consist of a very large, oblong, terminal leaflet, and two very small lateral ones. At night the primary petiole rises, and the terminal leaflet simply becomes deflexed close to the stem bearing the leaves; this crowding has the effect of reducing the area exposed to radiation. The very small, lateral leaflets are not sensitive to variations in the intensity of light, and do not sleep. So long as a high temperature is maintained they continue their jerking and zigzagging movements at all hours of the day and night. At the same time they are *circumnutating* or rotating upon their own axes, so that the upper surface is alternately directed to all points of the compass.

FIG. 5.—A LEAF OF THE SENSITIVE PLANT ASLEEP, OR AFTER IT HAS BEEN DISTURBED.
Compare with Fig. 4.

The false acacia (*Robinia Pseudacacia*) has pinnate leaves, with numerous pairs of leaflets and an odd or terminal one. The tree is frequently planted in streets and gardens, so that it may readily be observed during the day or evening. The day position of the leaf (Fig. 7, *a*) is horizontal, arched, or inclined, in a varying degree, even upon the same tree, according as the branches bearing them are erect or drooping. At sundown the leaflets begin to sink downwards, till in the early part of the evening they are perfectly perpendicular to the earth's surface (Fig. 7, *b*), with the opposite pairs in close contact back to back, and their upper faces exposed laterally. The terminal leaflet looks odd, for it hangs perpendicularly at right angles to all the rest, and does so by virtue of its position at the apex of the primary mid-rib. In the case of drooping branches it may be observed that the leaflets are perpendicular to the earth's surface, and do not form two right angles with their insertion on the mid-rib of the leaf. It is, therefore, evident that their chief object is to place themselves perfectly vertical at night, whatever the inclination of the branch bearing them

FIG. 6.—*CORONILLA VARIA*—AWAKE AND ASLEEP.
(a) Day position. (b) Night position.

may be. Fully matured or developed leaves sleep well after a bright day, but old and fading or poorly illumined leaves

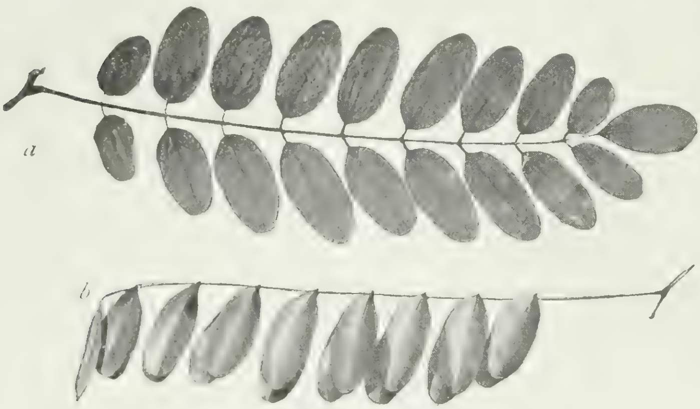


FIG. 7.—THE FALSE ACACIA (*ROBINIA PSEUDACACIA*): A FAMILIAR TOWN TREE.
(*a*) *Leaf awake.* (*b*) *Leaf asleep.*

cannot be expected to assume the correct or ultimate nocturnal position. Decaying leaves lose the faculty, and the tonic influence of light during the day is necessary for the proper accomplishment of the sleep movements at night, even in the case of younger leaves.

Abrus precatorius (Fig. 9), which furnishes the beautiful seeds known as "crab's-eyes," used as weights in India by jewellers and druggists, as well as in the formation of rosaries and necklaces, has pinnate leaves, without a terminal leaflet, and may be placed in the same group as the false acacia, from which it differs chiefly in this respect; otherwise the sleep movements are very similar in both.

The sleep movements of various species of *Cassia* are somewhat peculiar, especially in their ultimate position. When daylight is failing, the leaflets rotate or twist upon their axes, so that they face each other in pairs, as in *Tamarindus indica*. This is not the goal, however, and, the movements continuing, the leaflets next sink downwards till they are perpendicular, face to face beneath the mid-rib. The leaflets of many species reach the first stage, and many others the perpendicular stage, including *C. Absus*, *C. siamea*, and *C. grandis*. This is carried a step further in *C. occidentalis*, *C. corymbosa*, and *C. Tora*. The leaves of all are abruptly pinnate, but in these two latter species there are only three pairs of leaflets. At sundown, after a warm, bright day, the two pairs nearest the apex become directed backwards towards the base of the petiole, but beneath it. The two upper pairs of leaflets are directed between the lowermost pair. In extreme cases all are directed towards the bottom of the petiole. The ultimate position is just the reverse of what happens in *Coronilla varia* (Fig. 6), where the leaflets rotate on their axes, rise up above the mid-rib, and then turn towards the base of the upper side of the petiole.

The species of *Lupin* differ from all that we have been previously considering, and this by reason of their structure. The compound leaves are digitate, with a varying number of leaflets arranged during the

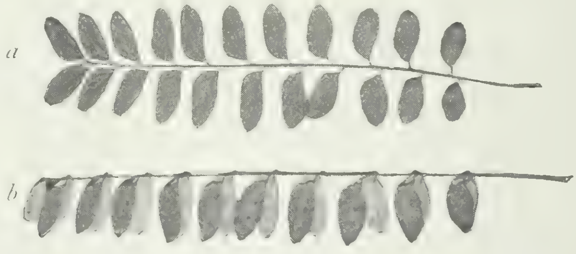


FIG. 8.—THE MAHOGANY TREE (*SWIETENIA MAHAGONI*).
(*a*) *Awake.* (*b*) *Asleep.*
This tree furnishes the mahogany of commerce.

day in the form of a horizontal star; that is, they stand in a circle round the top of the petiole. Only the younger ones sleep in a very marked manner. In *Lupinus*

arboreus and *L. subcarnosus* the leaflets become more or less deflexed till they resemble, in the aggregate, a half-closed umbrella, with their upper face exposed laterally. In another type, represented by *L. Hartwegii*, the leaflets all rise upwards till they resemble an umbrella that has been turned inside out by the wind. A more remarkable case is met with in *L. luteus* and *L. pubescens*. The short leaflets on the side of the leaf next the centre of the plant begin to sink downwards at nightfall, while the longer ones on the opposite side of the leaf rise up till they are vertical, with their apex to the zenith. Some of the leaflets in the middle position between these two sets merely rotate or twist upon their axes till their two lateral edges are turned to the earth and sky respectively. Thus we have three different types of sleep movement in the genus *Lupinus*, and possibly some other modifications exist. Moreover, in *L. pubescens* and *L. luteus* alone, one leaf exhibits three distinct movements, and the result is that the leaflets present the phenomenon of a vertical star when

FIG. 9.—*ABRUS PRECATORIUS*, AWAKE AND ASLEEP.
The seeds of this tree, known as "crab's eyes," are used for rosaries and necklaces.

the leaf is in a nocturnal position. (Figs. 11 and 12.)

It will have been seen that the form of sleep movement that takes place in the respective species depends upon the structure of the leaves, the presence or absence of pulvini, the length of the petiole, and the relative size and shape of the leaflets. In many cases it will be found that the night position of leaves that sleep corresponds very closely with the *vernation*, that is, the manner of folding in the bud stage. Pulvini may be compared to knee joints which facilitate folding, and if leaves do not always close at night in the same fashion as when folded in bud, it may be regarded that the joints are reversible, and also capable of twisting or rotating upon

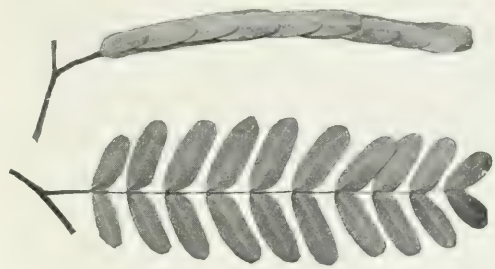


FIG. 10.—*TAMARINDUS INDICA*, ASLEEP AND AWAKE.

themselves. A beautiful instance of the relation between structure and movement is met with in *Tamarindus indica* (Fig. 10). The anterior half of each leaflet is wider than the other, as if to assist it in swinging round. This half is also bevelled away at the base, and when the leaf is in the act of assuming the night position it will be noticed that the bevelled edge lies parallel with the mid-rib, and just manages to clear it at a certain stage of the twisting. The stems of *Lespedeza juncea* (Figs. 2 and 3) are covered with innumerable leaves, and a large number of them surround the apex of the stem for some time previous to expansion, forming a half-open bud, similar to the fashion in which they afterwards sleep. Each leaflet is folded upon itself (*conduplicate*) in bud, so, when they afterwards sleep, they become more or less folded in the same manner, the mid-rib being the hinge, as it were, on which they turn. While still in bud all the leaflets of *Trifolium repens* are folded, the terminal one lying between the other two. When fully developed and assuming their nocturnal position they only become slightly folded; but the lateral leaflets attain this position in advance of the terminal one, so that the latter, having to

move through an angle of 180°, cannot get between the lateral pair. The leaflets of the false acacia (*Robinia Pseudacacia*) are folded in bud, and remain in this state till the leaf attains a length of several inches. At first they lie along the petiole with their edges to the sky; then they rise with their apex pointing upwards, and as the leaf gets older they become deflexed in the same manner as the adult leaves sleep. Finally they commence to expand at the bottom of the petiole, and open in succession to the apex of the leaf. Some of them remain slightly folded for a long time, or even permanently, whether asleep or awake. This may be due to the low temperature at the time when the late leaves are developed, and in some cases it seems to be due to variety.

The sleep movements of plants cannot be properly studied without considering *circumnutation*, or the spontaneous movements of leaves, for the night position is only a greatly modified state or stage of circumnutation, induced by the alternation of day and night; or it may be the sensitiveness of the leaves to light or its absence, which causes the opening and closing that we have been discussing. Young and growing organs, owing to the greater rapidity of growth, now on one side and now on the other, keep turning round in an orbit which is more often an ellipse than a circle. Nor is the movement continuous in one direction, but a sort of zigzag motion, alternately progressing and retrograding, sometimes jerking, as may be seen in the telegraph plant, which is an extreme case, and easily followed, owing to its rapidity. In the simplest case only one ellipse may be described during the twenty-four hours. In other instances there may be two, three, or more of these ellipses. The lateral leaflets of the telegraph plant have been observed to describe about a dozen irregular circles in forty minutes, when the temperature was above 100° F. A circle has been completed in 1 min. 30 sec. As these leaflets do not sleep, we need not further consider their movements, but they serve in a marked manner to give an idea of the spontaneous movements termed *circumnutation*.

FIG. 11.—A LUPIN LEAF BY DAY.
It forms a horizontal star.

FIG. 12.—A LUPIN LEAF BY NIGHT.
The "star" is now vertical.

When leaflets are drooping, it must not be imagined that they are flabby and merely hanging loosely, as in the case of leaves or leaflets that are flagging through lack or loss of water. They are held in that position as rigidly as their structure and texture will admit, and resist to some extent when an attempt is made to open them or lift them into the horizontal or day position.

That the sleeping and waking movements of leaves are generally due to differences in the intensity of light may be proved by experiment. In the ordinary course of nature leaves sleep only once in the twenty-four hours, though the spontaneous movements are more or less continuous, but greatly masked by the sleep movements. The latter may be induced at any time during the day, provided the conditions are suitable as to light, heat, and moisture, without which the experiment may be nullified. Some years ago experiments were made by the writer to determine

whether the night movements could be induced by artificial treatment. A plant of *Chloroxylon Swietenia* was put under a bell-glass, and shaded at 11 a.m. At 12 noon the leaflets were drooping at an angle of 45° to 40° ; at 2 p.m. many of the leaflets were nearly perpendicular ; and at 4 p.m. they were quite so. Another plant of the same species was put into a dark box in another part of the laboratory, with precisely similar results, at 12 noon ; but after that the leaflets refused to act, apparently as the result of too low a temperature, the experiment being conducted late in September. A plant of *Dichrostachys cinerea* was put under a bell-glass and shaded at 1.30 p.m., and at 2.30 p.m. the leaflets were completely closed up. Precisely similar results were obtained with another plant put into a dark box. At this point the shading was taken off the first plant and the other was stood in a sunny position without a glass covering. In both cases the leaflets were from half to three-fourths expanded at 5 p.m. *Prosopis juliflora* was put to sleep in one hour at the same period of the day as the *Dichrostachys*. One plant was put under a bell-glass and shaded, while another was placed in a dark box. Both plants were exposed to light at 2.30 p.m., and both were completely awake on the sunny side by 5 p.m. The opening movements were slightly more speedily performed under the bell-glass than without such protection, and the obvious inference was that the atmosphere of the laboratory was too dry for a plant that had been grown in the moist atmosphere of a hot-house.

From the study of different species it is evident that some are much more sensitive to variations in the intensity of light than others. A very interesting case in point is presented by *Cassia Tora*. At 11 a.m. one plant was put under a bell-glass and shaded, while another was put into a dark box. At 12 noon the basal pair of leaflets had turned vertically upon their edges, while the other two pairs were more or less perpendicular, especially those of the plant in the box. At this point both plants were fully exposed to diffused light, and the leaflets regained the horizontal position by 1 p.m., especially those of the plant under the bell-glass. The one exposed to the dry atmosphere of the laboratory suffered more or less, and the leaves drooped. At 1.20 p.m. the specimen under the bell-glass was put into a dark box, and by 2 p.m. the leaflets had assumed the nocturnal position. Both plants had been put to sleep in an hour, and both woke during the next hour under the influence of sunlight. The one under the more favourable conditions of the bell-glass was put to sleep for the second time in one day, and within three hours from the commencement of the experiment ; the second time it was put in darkness it took only forty minutes to induce the phenomenon of sleep. The plant which had suffered from lack of moisture had recovered by 2 p.m. by being put under a bell-glass ; it was then heavily shaded and put to sleep in half an hour. The first specimen was put in a sunny position under a bell-glass at 3 p.m., and in the course of one hour forty-five minutes it had completely resumed the day position. At 5 p.m. it then commenced the downward movements naturally, and at 5.50 had composed itself to sleep for the third time in one day. The first two sleeping and waking movements were artificially induced by heavy shading ; the third "nap" was caused naturally. The day was not particularly bright, there being no sunshine till 3.30 p.m. The temperature of the laboratory was about 60° F., dropping to 55° F. towards night.

Another interesting case is presented by *Abrus precatorius*, which may be put to sleep artificially and then roused. A plant was put into a dark box at 11 a.m., and in the course of two and a half hours all the younger leaflets were closely reflexed, back to back. At this point the plant was put into full sunshine, and in the course of fifteen minutes the leaflets had risen up to

an angle of 45° with the petiole, and in another period of the same duration the younger leaflets were quite horizontal. Thus only one-fifth of the time necessary to put the plant to sleep served to wake it. Another phenomenon was now observable, for the leaflets turned up in such a way as to face the sun. As the latter veered to the west the leaflets kept shifting their position; those on one side of the mid-rib turning downwards, while those on the other side turned upwards so as to present the upper surface to the orb of day. They followed the sun in this manner all the afternoon.

The object of the sleep movements is for the purpose of protection, and to avoid the ill effects of cold at night. The leaves of various plants have been killed by frost at night when the leaflets were pinned open, so that they could not assume the night position. Many species of plants that sleep in a marked manner are natives of tropical countries, and it might be thought that the faculty would be of no service to them; but it must be remembered that radiation of heat is often very great in tropical countries, and the temperature is then sufficiently low not only to retard growth, but even to stop it altogether if the leaves had not the means of protecting themselves by presenting the smallest possible surface to the sky, and therefore to the effects of radiation.

The tissue of leaves that sleep is often very thin—sometimes remarkably so—and presumably delicate. In this country the effect of a spell of fog and smoke is disastrous, causing the leaves to turn yellow and drop, thus showing how sensitive they are to the absence of light, especially when coupled with an impure atmosphere. The more delicate and fragile, the shorter lived they are. We can, therefore, easily imagine the evil effects of tropical storms, with a low temperature, and of hailstones in temperate climates. In addition to the faculty of closing to avoid the effects of heat radiation, *Porlieria hygrometrica* remains closed during periods of drought to husband the supply of water. Something similar may be observed in *Lespedeza juncea* and *Cæsalpinia japonica*, the leaves of which will close early in the afternoon of a windy day. Those of the former remain shut till a late hour of the day, if the morning is cold and radiation keen.

When animals go to sleep, all movements are suspended save that of breathing or respiration, and the beating of the heart, with its attendant circulation of the blood. Their senses are steeped in forgetfulness in proportion to the soundness of their sleep. The sole object of sleep in animals is to rest, so that they may recuperate from the effect of their exertions during the day or night (according as their habits are diurnal or nocturnal), and thereby regain their wonted energy and activity. Sleep in plants is brought about by a diminution of light on the approach of night, and the object is to protect them from the ill effects of a low temperature when the sun has ceased to warm them. The spontaneous movements are continued during the night, and the tension of the sap in the tissues is then greatest.

A FAMILY GROUP WHEN THE WORLD WAS YOUNG.—THE KITCHEN-MIDDENERS AT HOME.

THE KITCHEN-MIDDENS AND THE MEN WHO MADE THEM.

THE student who has eyes and has learned to use them cannot walk along our own shores—or, indeed, along the shores of almost any part of the world—without observing the ceaseless warfare which is being waged between the sea and the land. The waves are breaking against the cliffs—those "eternal walls," which seem to the ordinary spectator the visible type of unchangeableness—returning again and again to the charge, until in time they undermine the great bulwark, and sweep it into the bosom of the ocean. Again they renew the attack, never idle, always busy, until, yard by yard and rood by rood, the sea eating into the countries bordering it, the coast-line is altered, and old historical landmarks live only in the books of chroniclers. If this went on for ever, by-and-by the sea would roll over the whole world. But there is a counterbalancing influence at work. The result of this influence we see in the form of the long line of shells and other marine refuse which encircles many portions of our coast. At first glance we might suppose this to be caused by the winter storms dashing the spray, and the *débris* along the beach with it, high above the ordinary tidal mark. But a slight examination shows that this theory is mistaken.

In those old sea-beaches lying some way inland from the present ones, we see that the material of which they are composed is much the same as that on the shore over which the sea rolls twice a day. Shells are their chief constituents. The shells, moreover, are to a great extent unbroken, and, in many cases, evidently in the position in which, when they contained living creatures, they had lived in the sand and mud in which they are still imbedded. It is at all events clear that they have not been disturbed by the hand of man, and that the beaches on which they lie were elevated by a slow rise of the land. This rise is, we know, going on in many parts of the world to the present day, while in others there is an equally clear and gradual sinking of the shores. But if we prolong our investigations, we shall come upon other shell-mounds which, though at first sight seemingly the same, are in reality very different. For instance, on certain portions of the coasts of the Danish isles, we come upon enormous accumulations of dead shells, sometimes five to ten feet in height, several hundred feet in length, and in many instances one hundred to two hundred in breadth. We see that these mounds occur only at intervals. That in itself is not important, for the whole coast, even when of the same character, need not necessarily have afforded places for the occupants of marine shells to live. We also see that these mounds are elevated, like the old sea-beaches, at considerable heights above the sea-level. A closer examination of the Danish shell-mounds, however, reveals many differences. For example, while, on the neighbouring shores and in the raised sea-beaches spoken of, the shells are of all ages, in the mounds under consideration they are chiefly adults, the young being notably absent. This could scarcely happen if the deposit had been due to the action of the sea alone. Again, these mounds are not composed of the shells of molluscs all living in the same locality, and therefore could not have been found naturally in each other's company. This at once strikes a fatal blow at the theory that they belong to a raised

sea-beach. Nor do we find the heaviest shells lowest down, as is always more or less the case when water has had anything to do with the sorting of materials. On the contrary, we find big and little, light and heavy, mixed up in such a manner that it is evident that since the component members of the shell-mounds came—no matter how—into the position they now occupy, the sea has had nothing to do with them. On examining these mounds more closely, it is found that they contain the bones of animals, and among these the bones of some species now extinct, but which it is known existed in the north of Europe within historical periods. A still more exhaustive search discloses a few of the most primitive tools. These consist of rudely formed weapons of flint, with splinters which have evidently been detached in the manufacture by chipping of their primitive knives and arrow-points (Figs. 1, 2, and 3). Along with the flint weapons—which show, without any possible doubt, the presence of men at the time these mounds were formed—we find some rude pottery (the work evidently of the most untutored artists), an implement which is believed to have been a spindle, charcoal, and cinders. The bones are those of wild animals, such as might be used for food. No domestic animal, except the dog, has left any trace in these shell-mounds; and in vain do we search for the presence of iron or of that bronze which, according to archæologists, was characteristic of a still earlier and less civilised people than those who constructed their weapons and domestic utensils of iron. We are thus led to the inevitable conclusions that:—

(1) These curious heaps or mounds are the work of man, seeing that we cannot account for their peculiar formation under the assumption that they are due to natural causes.

(2) This particular race of mankind must have lived many long ages ago, otherwise the bones associated with them would have been those of animals either now found in Denmark, or which have become exterminated at a later period than we know the bones of those found in these mounds have.

(3) These men must have been of a very low order of development, and their knowledge of the metals must have been particularly scanty; certainly they must have been very different from the people who have inhabited Denmark during historic times.

These are the conclusions from the premises before us—and very justifiable ones, too, according to all scientific methods of reasoning.

The next step in advance is to find out, if we can, who were the people who made these shell-mounds, and for what purpose or in what operations they were made. Now, should we confine our observations to those on the Danish coast, we might arrive at sufficiently accurate conclusions; but still, as the data are limited, it is as well to inquire whether such mounds are confined to the shores of the Scandinavian islands, or are more widely spread. Following up this investigation, we find that not only have they been observed in the island of Zealand, Zeeland, or Sæland, that on which Copenhagen is built, and especially along the shores of the shallow inlet known as the Isefjord, but they are also found on the coasts of the isles of Fünen (Fyen), Moen, and Samoe, in Jutland (Jylland), along the Liimfjord, the Mariagerfjord, the Randersfjord, the Kolingsund, and the Horsensfjord, and, most probably, also along the southern part of Denmark, though still waters seem to have been loved of the shell-mound builders. It is, however, possible that the reason why we find them in such localities is because on parts of the coast where the sea wears away the shores they have long ago disappeared, a great portion of Denmark being elevated but little above

the sea-level. They are also found in close vicinity to the water, the exceptions to this rule being in cases where it can be proved that their *locale* has been altered either by slow elevation, by silting up the sea with mud, or by the formation of peat, which has made inroads on the sea. In no case, however, where they have been undisturbed are they found within reach of the waves even during the roughest of weather—another proof that those who formed them must have lived in their close vicinity, otherwise they would not have been so careful to put out of reach of destruction heaps of materials so seemingly valueless, though artificial.

If we may have formed any theory which would make these shell-mounds in any way specially connected with the north, or its early civilisation, it is speedily dissipated by discovering

FIG. 1.—RELICS OF THE OLD STONE AGE.

1, a spoilt flint; 2, a scraper, used probably in dressing skins for clothing; 3 and 4, small spear or arrow heads.

FIG. 2.—RELICS OF THE OLD STONE AGE.

1 and 3, spear heads; 2, a knife; 4, probably a spoilt spear head.

that not only are they found in Denmark but also in Sweden, and not only in Scandinavia but also in the extreme south of Europe—for near Mentone, in the Gulf of Genoa, are heaps almost identical—and likewise along the shores of Great Britain. The latter are, however, to all appearance, judging from the remains, the work of a people of a later date, though the uses to which they have been put are identical. The Scottish shell-heaps bring us nearer to our own times, and lead us to ask whether or not people in a low stage of civilisation—in other words, those who are familiarly called savages—have not in their belongings something similar to those old shell-heaps of the shores of Europe? We do not require to seek far afield, for wherever we find a coast tribe of savages, they live to some extent on shell-fish, and whenever they have abundance of shell-fish to live upon they have, not far from the doors of their huts or wigwams, formed mounds which are identical—except, of course, in the kind of shells and other remains composing them — with those which we have already briefly described. Along the shores of North America, on those of Brazil and Ecuador, and even in

Australia, these shell-heaps are found. From Newfoundland to Florida there are immense mounds of them at intervals along the coast, and they may be seen on the shores of Vancouver Island and British Columbia, where, as at Beacon Hill, in the vicinity of Victoria, they contain flint weapons no longer used among the coast natives. In these regions we do not, however, require to speculate regarding their mode of formation, or presage it from an inductive study of the contents, for they are still being formed. They are, in brief, the refuse heaps of the lazy, mollusc-loving Indians, who eat the clam, the cockle, or the oyster, and toss the shells outside their doors. They devour a wild duck, a grouse, a salmon, a deer, or a beaver, and deposit its well-picked bones in the same general receptacle. They split the elk's leg bones to obtain the marrow, and into the refuse heap go the *disjecta membra* of that marrowless femur and tibia. A hunting spear is broken, and in due time to the refuse heap go the fragments. In a word, when the hunter's lodge is swept—and even Indian lodges are sometimes swept—all the fragments of his meals, his sports, and his industries, such as they are, are deposited among the shells close by. But if there is on the muddy flat within a stone's throw of their door a bed of clams, or other molluscs, naturally it forms the staple of the Indian family meals, and its bulky shell accordingly composes the greater part of the ever-increasing shell-mound by the single hut, or the hamlet where the ichthyophagous fishers live. Indeed, it sometimes happens that these shell-mounds, and other refuse heaps, become so uncomfortably large that the Indians have to remove the village. In a more refined state of society the refuse would first have been removed, but lower down in the scale of civilisation things often go by contraries. But we need not go all the way to Vancouver Island to see such a shell-mound in process of accumulation. At any fishing-village along the coasts of England or Scotland an almost exactly similar one is being formed in front of the village doors. Ask the fisher-folk of Yorkshire, Northumberland, or Lowland Scotland what such a mound of oyster, cockle, and mussel shells and other domestic refuse is called, and they will tell you a "midden"—an expressive old word of Danish origin, which has unhappily been allowed to drop into oblivion, or to be consigned to the limbo of too homely or slightly vulgar expressions. Need we, therefore, doubt what are the Danish and other shell-mounds of which early in this paper we made the acquaintance? They are the refuse heaps of the very ancient coast tribes—we shall not say savages—who dwelt along the coast of Denmark before books were written, or runes engraved by mortals loving immortality. Indeed, so evident is this that the Danes have applied to them the name of *Kjoekkenmoeddinger*,* or "kitchen-middens," from *Kjoekken*, "kitchen," and *Moedding*, "refuse or rubbish heap." Under this name, accordingly, they are now known to science, and "kitchen-middens" we shall accordingly designate them so long as we ask the reader's attention to the curious tale which they reveal.

What, then, do we learn from them? Lordly monuments some nations have left to record their prowess or their greatness. The frail huts even of the rude rearers of the kitchen-middens have long ago passed away. Others leave their records on their tombs—if not in inscriptions, at least in their arms and utensils, which are buried with them, to be used in the happy hunting-grounds; while the tell-tale skull enables us to know what manner of intelligence this

* This spelling is now somewhat archaic, and has given place to *kokkenmoddinger*.

unlettered forefather of ours had. But no trace of carven stone, not a bone of his body, not a weapon save the rude flint spear head, not a domestic utensil save the broken potsherds which were tossed aside as worthless, have descended to us who have come into the heritage of the Kitchen-middeners. A people have passed away, and left their history to be deciphered from their dunghills!

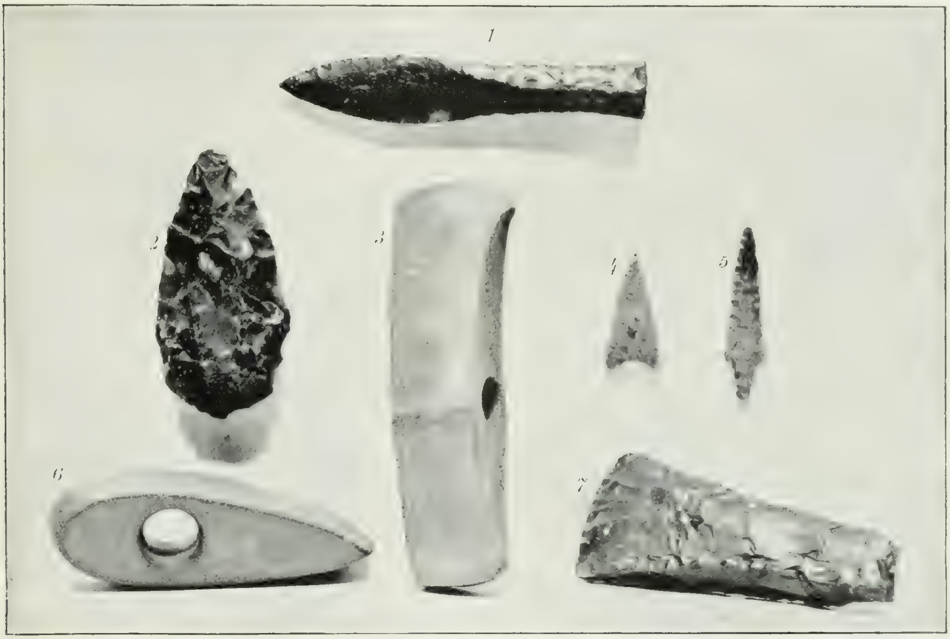


FIG. 3.—MORE FLINT WEAPONS USED BY THE KITCHEN-MIDDENERS.

1 and 2, spear heads; 3, an axe drilled for a handle; 4 and 5, types of arrow heads commonly used; 6, an axe hammer also drilled; 7, another type of axe.

Yet that history is not an uninteresting one, and the materials we have to deal with have, in careful hands,* proved much less deceptive than many a ponderous volume of flattering chronicles. It is evident that the life of the people who accumulated the kitchen-middens was a merely animal one. If they had a higher life than that which was devoted to supplying their slender wants, we shall never know it. There is no likelihood that they knew anything of the art of agriculture, or that, with the exception of the wild berries of the woods and moors, they had any vegetable food. As sea-weeds are scarce in the Baltic, it is not probable that, like the Eskimo, they could vary their flesh and fish diet with this homely fare. In some of the mounds there are remains of charcoal and ashes, and in the contiguous soil a dark, carbonaceous-looking matter which is probably the ashes of the eel-grass, or *bændeltang* (*Zostera*)—about the only marine plant which at this day borders the coasts of the Danish islands. Less than two centuries ago this eel-grass was employed for making a coarse salt by macerating the leaves of the plant, and it is not unlikely that those very old Danes also used this means for obtaining some material to

* In addition to much information obtained directly in Denmark and elsewhere, and from the original investigators and their collections, the data here given owe nearly everything of value to the researches of Steenstrup, Worsae, Forchhammer, and Lubbock (now Lord Avebury), and to the memoir of Morlot in the *Bulletin de la Société Vaudoise des Sciences Naturelles*, t. vi.

flavour their tasteless diet, the Baltic being only brackish, and not a very promising source for salt. The shells which make up the greater part of the kitchen-middens are the common oyster, cockle, mussel, and periwinkle (*Littorina littorea*), their relative frequency being in the order in which they have been mentioned. Here we see evidences of some great physical and biological changes. The oyster, which seemed to have formed the bulk of the meals of those simple Epicureans, has now almost entirely disappeared from all the regions east of the Kattegat, and more southerly than the shore-line of Zealand. In the Kattegat even it now only exists in isolated individuals, and nowhere in such abundance as would supply food for any great number of people, even with that toil in searching for them which hungry and most likely very lazy Kitchen-middeners would never devote to them. At one point only—namely, between the island of Læssö and the northern extremity of Jutland—has an oyster-bed ever been worked within the memory of man. At one time a few were got from a locality at the entrance to the Isefjord; but the great increase of the common starfish, which preys on them, led to their extermination. Yet in ancient times the whole of the Isefjord was one great oyster-bed, and in that inlet there can still be seen *in situ* dead shells, showing that the creatures originally in them must have been destroyed by some physical change in their surroundings—probably by a decrease in the saltness of the Baltic. We also find the periwinkles and cockles of the kitchen-middens larger than those at present found in the Baltic. In addition to the oyster, periwinkle, and cockle, we find in these monuments of the gastronomic tastes of the very old Danes the whelk (*Buccinum Nassa* and *B. undatum*), both of which, though inferior food, are still eaten, and *Venus palustra*, also an edible shell-fish, though, like the other two, not much in request, and rather rare in the Danish waters. Crabs are uncommon in the sea adjacent to the sites of the old fish-eating savages, and accordingly there are few traces of any kind of crustacea. Cod (or, perhaps, torsk), flounder (or dab), and eel bones are, however, abundant, but those of the herring are the most common of all. These remains not only give us an inkling as to the dietary of these extinct savages, but also enable us to learn that they must have had canoes; otherwise they could not have procured oysters, which are found in deep water, while the herring and cod rarely come in so close to the shore as to be able to be captured by a people without some kind of craft, either rafts or rude "dug-outs," such as are used by the least mechanical of modern barbarians. Eels—a favourite dietary of the Kitchen-middeners—seem, curiously enough, to have been in these remote times common in the same localities as they are in our day. For example, the neighbourhood of the town of Aalborg is, as the name of the place signifies, famous for its eels, and it is just in this vicinity that the kitchen-middens yield the greatest number of their bones. As might be expected from a shore-living people, aquatic and palustrine birds were those which they chiefly used as food—among these, the wild swan, wild geese, and various species of ducks. The capercailzie's (*Tetrao Urogallus*) bones are also found; and, what is still more interesting, in the kitchen-middens we come upon remains of the all but wingless bird, the great auk (*Alca impennis*), which, owing to the facility with which it was killed, is believed to be extinct now. At all events, none have been seen in its old haunts, and a specimen would nowadays be worth rather more than the conventional "king's ransom." At one time it was so exceedingly abundant in Iceland, Newfoundland, Orkney, and other northern localities,

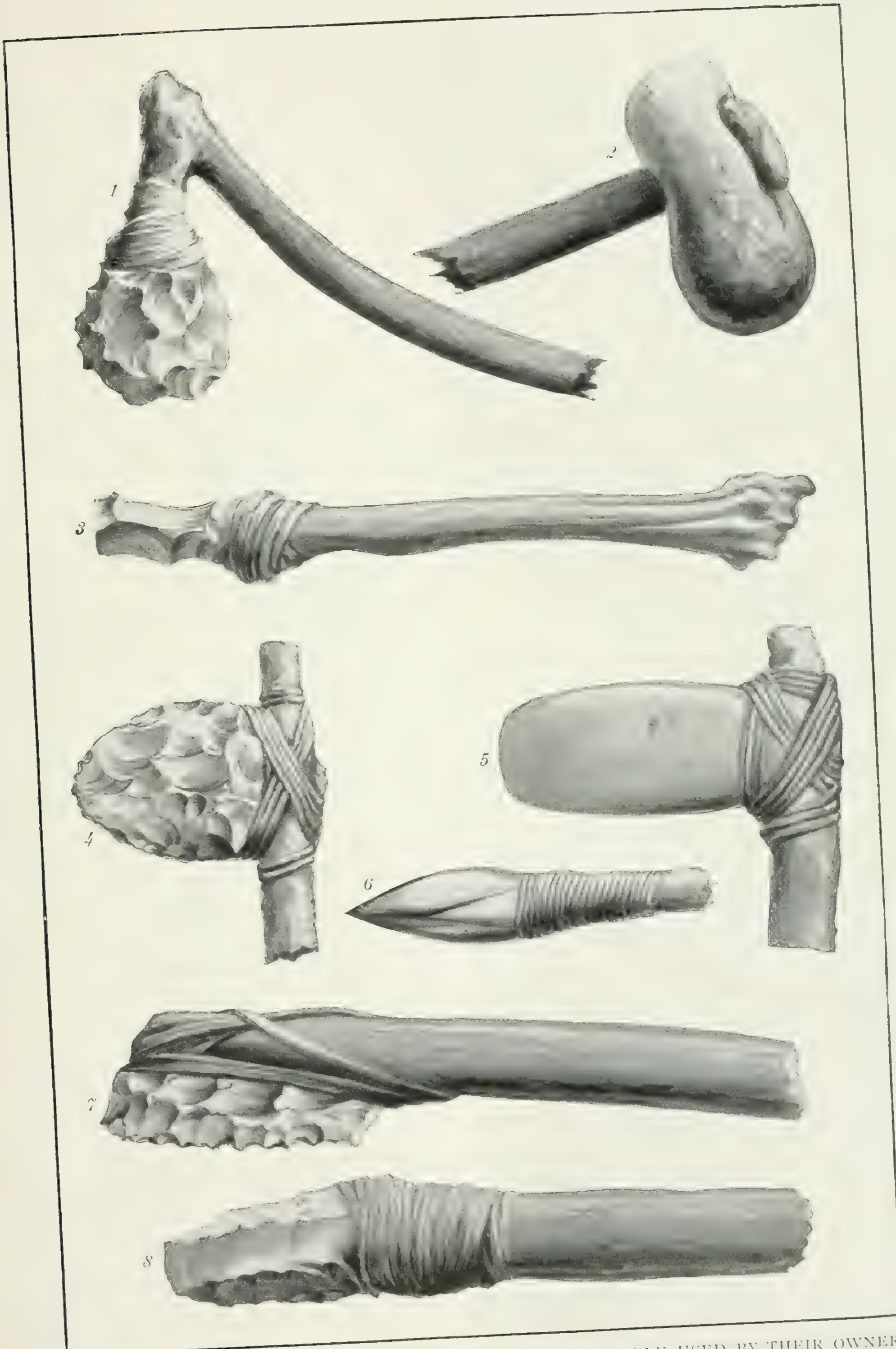


FIG. 4.—SHOWING HOW THESE FLINT WEAPONS WERE PROBABLY USED BY THEIR OWNERS: LASHED TO RUDE HANDLES BY SINEWS OR STRIPS OF RAW HIDE TAKEN FROM THE ANIMALS THEY KILLED.

1, a much chipped adze; 2, a hammer; 3, a chisel; 4, an axe of chipped flint; 5, an axe, polished; 6, a spear head, ground; 7, a saw; 8, a rough knife.

that ships' crews were in the habit of provisioning their vessels with it, and no doubt the old Kitchen-middeners found its squat, fat carcase an easily acquired addition to their by no means monotonous diet. The domestic fowl is absent, nor have the *kjoekkenmoeddinger* yet yielded any remains of the two swallows which now frequent Denmark, nor of the stork so common on roofs and on church towers in that country, and the domestic sparrow of cosmopolitan habits. The most numerous quadrupeds which—judging from the relative abundance of their remains in the shell-heaps—supplied the "table" of the Kitchen-middeners seem to have been the red deer (*Cervus elaphus*), the roe (*Cervus capreolus*), and the wild boar (*Sus scrofa*)—the last now extinct in Denmark.

The urus (*Bos primigenius*), the beaver (*Castor fiber*), and the grey seal (*Halichœrus gryphus*) are also so often met with that they must have supplied much of the food of these primitive people. The beaver has not been known as an inhabitant of Denmark for more than 900 years. The seal, though rare, is still occasionally seen in the Kattegat; while the urus or wild ox has been long ago extinct. It was seen by Cæsar; and one of the last records we have of its existence in Europe is in a manuscript of the tenth century, in which it figures among the viands that appeared on the tables of the monks of St. Gall, in Switzerland. The remains of the elk and the reindeer have not yet been found in the kitchen-middens, though it is highly probable that they were contemporaries of the people who made these mounds. Among other quadrupeds, the bones of which have been disinterred from these refuse heaps, are those of the wolf, the fox, the lynx, the wild cat, the sable, and the otter; but none of them are so common as those already noticed. The bones of the hedgehog and the water-rat are also occasionally found, as well as bones gnawed by these latter animals. No trace of the hare, a common animal in Denmark, has been found. This curious omission may be accounted for by the fact that, from very early times, the northern people have regarded this animal with superstitious feelings, and accordingly the Kitchen-middener might have objected to eat it, except when compelled by the direst necessity. A small-sized dog is the only domestic animal whose bones have been found. Its habits seem to have been very much the same as its modern representative's. Give a domestic dog the carcases of birds to devour, and it will be found that it will swallow all the bones except the long ones. Accordingly, it is interesting to find in the kitchen-middens numerous gnawed long bones, off which all the cartilaginous parts have been stripped, and on which the marks of the teeth of these old carnivora are distinctly seen. It is also not unlikely that the Kitchen-middeners ate the dog, as is still done by many modern savages, and, indeed, by some people who would be shocked to have such a name applied to them, for on its bones are often found suggestive marks. The bones of young nestling birds, of which at present there is a great consumption in Jutland, are absent from the kitchen-middens. We must not, however, conclude from this negative evidence that the primitive people were absent from the Danish shores from May to August on a prolonged summer holiday, for it is more than likely that the dogs which rejected the long bones of birds, as inconvenient to swallow, devoured the slender and all but cartilaginous skeletons of the young ones, just as some people devour quails whole. Indeed, we know that these men must have resided on the shores of old Denmark during the whole year, for in their refuse heaps we find the horns of the deer or roebuck, as well as the embryonic skeletons of these species,

and of the wild hog. The presence of the bones of the wild swan (*Anas cygnus*) show clearly that the Kitchen-middeners must have been on the coast during the winter, for it is only during the winter that this bird makes its appearance in Denmark. On the approach of spring it betakes itself to still more northern regions. "It is then especially," writes M. Morlot, "that is heard its harmonious song, partaking of the sound of distant bells, and of the Æolian harp, whence, doubtless, the myth of its death-chant." It is, therefore, in the highest degree probable, though we have no distinct evidence of the fact, that a people who frequented the bleak shores of the Baltic during the winter, would also live on them during the pleasant Northern summer.

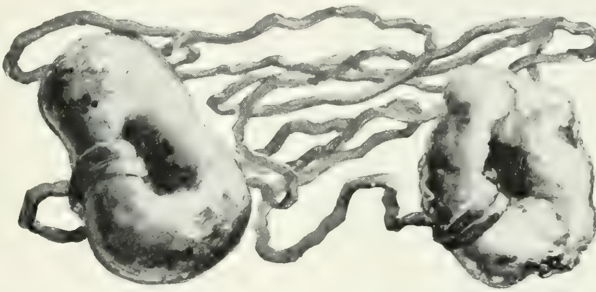


FIG. 5.—THE PROTOTYPE OF THE SOUTH AMERICAN BOLAS.

What the Kitchen-middeners did with their dead we know not. Perhaps they burned them. At all events—unless some round little Lapp-like skulls found in the peat are theirs—no actual traces of the men whose "middens" we have been investigating have been found. Here and there in some of them we come upon a skeleton, but these skeletons are simply those of some shipwrecked seaman, who has been buried in the dunghill of a race who have, like him, left no record behind them. The people who came after the Kitchen-middeners, judging from the imposing tombs which they have built, seem to have been great respecters of the dead; and, no doubt, so were their predecessors. But all is conjecture. There are, however, no grounds for believing that they were cannibals, for in these remains of the barbarous feasts, those of men never occur. A few rude flint or whinstone weapons, and some bits of pottery moulded by the hand (and, as is the case with the pottery of some savage people of our day, mixed with sand to prevent it cracking in the fire), are the chief traces of the handiwork of the people about whose dinners we know so much. Here and there we find—on the sea-shore—hearths of stones, on which, it is probable, on some of their fishing excursions, the Kitchen-middeners cooked their rude meals; and mixed with the pottery, it is observed, is some of the sand formed by the action of fire on the granite stones out of which these fire-places are formed. These angular sand grains give the pottery a better consistence. Hence the Kitchen-middeners, though a primitive, were not altogether an unobserving people. The flint weapons are mostly very rude, but now and then one of a more elaborate construction is found, and the marks on the bones split for marrow, and on others, show that they used comparatively sharp knives for separating the flesh. So that the presence of splinters and roughly chipped tools in the kitchen-middens may only mean that they threw away the badly made or spoilt ones, and kept the finer specimens, which would account for their rarity in the refuse heaps. There are also found in the kitchen-middens numbers of roughly hewn pebbles, specimens of which are also picked up imbedded in the neighbouring peat-bogs. These, it is believed, were sling-stones or weapons of some sort thrown at birds or larger game, or perhaps at each other in their tribal

wars. Bits of cut deer-horns, awls, chisels, and even combs, neatly fashioned out of bone and horn, have been among the "finds" in the refuse heaps of this shadowy race. One other fact we may note, and that is that in the fabrication of their instruments and objects of bone they selected that portion of the skeleton of the animal which is densest and strongest—namely, the inner side of the radius, or chief bone of the fore-leg. This proves, in the absence of other direct testimony, that these primitive Scandinavians were by no means deficient in powers of observation.

Who these people were we know not, and as to whence they came, or in what manner they disappeared, history is equally silent. Nor is it any more likely that we shall ever learn the fate of the Kitchen-middeners, than "what songs the Sirens sang, or what name Achilles assumed when he went among women." It is vain to speculate as to the gods they worshipped or the demons they feared—as to what were their loves and their hates; or, in this earthly here, of what kindlier hereafter they dreamed. It would be equally idle to try to fix an even approximate date for their era. All we can say is, that the Kitchen-middeners must have lived a long time ago. In all likelihood, there have been, since the time this ancient people flourished, some changes in the physical geography of the Baltic; though this need not excite surprise, as it is considered by many probable that the Oxus has changed its course within historical times, and the Runn of Kutch is, we know, of very recent date.

We have seen that the size of the shells makes it likely that the sea was, at the time of the formation of the kitchen-middens, salter than at present. It is just possible that this may have been owing to the Baltic in early times being in communication with the Arctic Sea, or, through wider channels than the present one, with the German Ocean, though this is a question too intricate to discuss in this article. The presence of the capercailzie in the kitchen-middens also suggests that the Scots fir (*Pinus sylvestris*), on the buds of which it feeds, at that time clothed the shores of Denmark, though since the dawn of history the fir has never been known as a wild tree of the country. In the peat-bogs we find a layer of it, and over this layer one of oak, and over all is growing the prevailing and characteristic tree of Denmark, the beech, which is so familiar nowadays as the chief ornament of the wooded shores of the Sound. Did a stronger race, armed with weapons of bronze, appear in the country, and, after the manner of stronger races generally, civilise the Kitchen-middener off the face of the earth? Were they driven to the inhospitable Land of the North Wind, and are they known now as the Lapps or Finns? Did some catastrophe—some great inroad of the sea, such as that to which the Danish isles are no strangers—overwhelm the humble dwellings by the side of the dunghills? There are vague evidences, which some think sufficient, to prove this. Or did the Kitchen-middeners gradually dwindle and die, a prey to their own exclusiveness? We cannot say. All that we are certain of is, that at very early periods—perhaps contemporaneous with the Cave Dwellers of England, France, and Belgium—there lived on the Danish shores a rude race who left no more pretentious monuments behind than the litter of their dinners, and that in the study of these refuse heaps modern *savants* have exercised their reasoning powers in writing the history of a vanished race.

WHAT ARE THE X-RAYS?

By T. C. HEPWORTH.

THE closing years of the nineteenth century will be memorable for many things, and one of the most important among them is the discovery of what are known as the X-rays. And this discovery is not merely a scientific curiosity, but has had far-reaching effects in the saving of life and the alleviation of pain.

The foundation of the discovery was laid about thirty years ago by Sir William Crookes, whose researches into the mysteries of radiant matter, illustrated as they were by remarkable experiments, aroused much interest among scientific men at that time. Crookes then stated his conviction that radiant matter was a fourth state or condition, as far removed from the state of gas as gas is from a liquid. And it is also noteworthy that he used the following remarkable words, which, in view of what has since occurred, seem to be prophetic. He said : " We have actually touched the borderland where matter and force seem to merge into one another, the shadowy realm between Known and Unknown which for me has always had peculiar temptations. I venture to think that the greatest scientific problems of the future will find their solution in this borderland, and even beyond ; here, it seems to me, lie ultimate realities, subtle, far-reaching, wonderful."

In the course of his experiments, Crookes devised a number of different forms of vacuum vessels—that is to say, vessels of glass exhausted of air until the trace of air, or other gas left, represented about the one-millionth of an atmosphere, and in some of these tubes were placed, previous to their being exhausted and sealed up, various substances. Shortly afterwards what was known as a " Crookes tube " became a familiar thing in all physical laboratories throughout the world. It is important to remember this circumstance, for the discovery of the X-rays was due to such a tube, and without it their recognition would have been impossible, or, at any rate, postponed to an indefinite date. It will be as well, therefore, if the nature of this tube be well understood before we go further into the matter of Röntgen's discovery of the X-rays.

We may for the sake of convenience liken the Crookes tube to one of the now familiar electric glow lamps which we see in so many business premises and private houses. The current is conveyed to such a lamp by platinum terminals, which go through the glass walls and are actually sealed into them. The delicate carbon

Photo: T. C. Hepworth.

FIG. I.—CROOKES TUBE CONTAINING A SALT OF STRONTIUM: PHOTOGRAPHED IN DAYLIGHT.

filament, which becomes incandescent when the current flows through it, is attached to these wires. Now imagine a glass globe with a platinum wire sealed into it at each side, but minus the carbon

filament, while at the lower end is an opening by which it can be attached to a pump, which is able to exhaust it of air. When the current of electricity from an induction coil is sent through such a tube, the necessary connections being made through the platinum terminals, the spark will jump from one terminal to the other so long as the air remains within the globe. But directly we begin to work the pump a change occurs. The spark disappears, and the globe is filled with a beautiful glow of lambent light. If we go on pumping so as to carry the exhaustion of the tube further, this glow arranges itself into layers, and this appearance is known as the "stratified discharge." With continual pumping a further change occurs. A dark space is perceived at the terminal where the current leaves the tube, otherwise known as the *cathode*, and this space expands until it quite fills the tube; but although the glow has gone, the glass walls of the tube assume a beautiful apple-green phosphorescence. A tube, when it has reached this stage, will give forth the invisible radiations called X-rays.

Photo: T. C. Hepworth.

FIG. 2.—CROOKES TUBE, CONTAINING STRONTIUM: PHOTOGRAPHED AT NIGHT BY ITS OWN LIGHT.

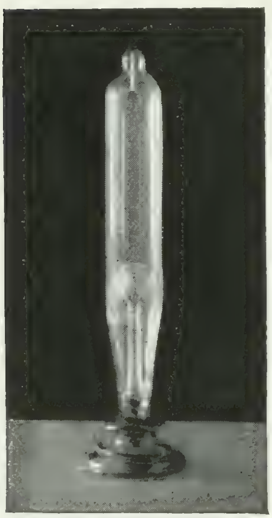


Photo: T. C. Hepworth.

FIG. 3.—CROOKES RUBY TUBE, BY DAYLIGHT.

In the exhaustion of a Crookes tube a mercury pump (Sprengel's) is commonly employed, and heat is applied to the tube at the same time to aid in the operation, which is a very difficult and protracted one. With such a tube Crookes found that under the stimulation of the electric current there were emitted radiations which travel in straight lines throughout the tube, which cast shadows of anything put in their path, and which excite brilliant fluorescence in certain minerals placed within the tube. For example, rough rubies studded on a kind of porcelain boss in the centre of one of these tubes were caused to glow like red-hot coals. The writer has made several attempts to photograph these tubes in a dark room by their own light, and it will be seen by the annexed illustrations that these experiments have been successful. Fig. 1 is the photograph of a tube partly filled with salt of strontium, taken in ordinary daylight, while Fig. 2 is the same tube taken by its own light in an otherwise dark room. Under the stimulation of the electric current this tube glows with a brilliant yellow light.

Photo: T. C. Hepworth.

FIG. 4.—CROOKES RUBY TUBE, PHOTOGRAPHED AT NIGHT BY ITS OWN LIGHT.

In Fig. 3 is shown a daylight photograph of the ruby tube above described,

and in Fig. 4 it is shown as photographed by its own light. As far as I can ascertain, no photographs of this nature have been previously produced. That of the ruby tube was the last of several attempts, for the light given by the glowing rubies is bright red, while the tube itself seems to be filled with an apple-green light, both of which colours were very non-actinic and required a long exposure.

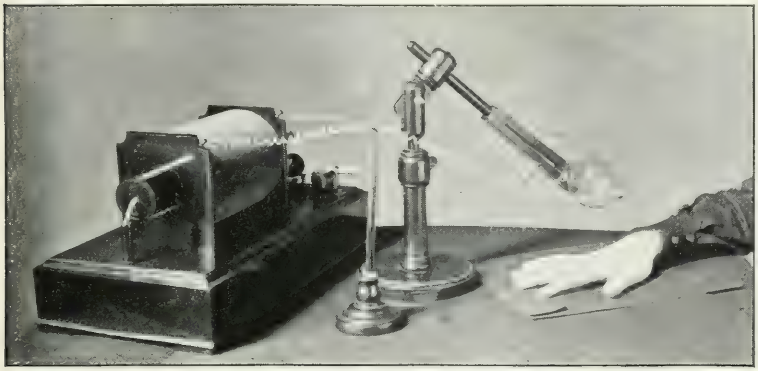


Photo: T. C. Hepworth.

FIG. 5.—THE X-RAY APPARATUS AT WORK.

The hand is placed upon a sensitive photographic plate which is wrapped in several thicknesses of opaque paper to protect it from the action of light. A "radiograph" of the hand is then taken.

We may now conveniently consider the rest of the apparatus necessary for producing these wonderful X-rays (Fig. 5). A battery or other source of electricity is, of course, needful in the first place. I have drawn my supply from the street main, but I prefer to work from a battery —and for choice from an accumulator, or secondary battery. The wires from the battery are carried to an induction coil, and the induced or secondary current is employed to excite the Crookes tube.

Faraday discovered long ago that a current traversing a wire was able to *induce* a current in another wire near at hand. This he called "the induced current," and many instruments have been devised to demonstrate its presence. The chief of these is the induction coil shown in Fig. 5. It consists of a core, composed of a bundle of iron wires, around which lie two layers of thick copper wire, or tape, thoroughly insulated. This forms the primary coil. Wound on this, but at the same time insulated from it, is a thick coil of very fine silk-covered copper wire, so fine that in the coil illustrated there are six miles of it, although the instrument is only about eight inches in length.

The battery is joined up to the primary coil, and every time the connection is made or broken the induced current flows through the secondary coil, but only at those moments. There is, therefore, a piece of apparatus attached which works like the hammer of an electric bell, whose duty it is to make and break contact several times a second by means of its vibrations. Thus we have what appears to be a continuous, but is really an intermittent, current of electricity traversing the secondary circuit of the induction coil.

Photo: T. C. Hepworth.

FIG. 6.—MR. JACKSON'S FOCUS TUBE.

And in its passage through this piece of apparatus the electricity seems to have undergone a strange transformation. So long as we have a simple battery current to deal with we find that it will not spring over any obstacle. Supposing, for instance, that we take the two terminal wires of a powerful battery, and make them

touch one on each side of a piece of thin paper. That fragile partition, measuring not more perhaps than the $\frac{1}{100}$th of an inch in thickness, is quite sufficient to prevent any current passing from one terminal to the other. The shock from such a battery is perceptible, but by no means dangerous, or even unpleasant.

The induced current, on the other hand, will spring over a considerable distance, and an induction coil is usually classed by the space over which its spark will jump. Thus we speak of a 4-inch, 6-inch, or 12-inch coil. The one shown in the illustration will give a 6-inch spark. This spark, when allowed to act for a few moments between the terminals of the coil, has all the appearance of a miniature thunderstorm, the lines of light assuming that peculiar branched appearance seen in so-called forked lightning. The induced current also resembles lightning in its disruptive effects, and in the terrible shock which it will give—a shock which, in the case of a large coil, would be fatal. Great care must therefore be exercised in the use of this apparatus. Every coil is furnished with a commutator, by which the connection with the battery can readily be broken without detaching the wires, and such disconnection should be invariably made when shifting any piece of apparatus in the course of experimental work.

It is curious to note that the discovery of the X-rays very nearly came to Sir William Crookes himself, and it was an unkind and certainly undeserved freak of fortune that he just missed it. One day, when he had some photographic plates near the apparatus, he found upon developing them that they bore certain marks which corresponded with his fingers. Thinking that these were blemishes due to faulty manufacture, he sent the plates back to the makers with a few very strong remarks. He had taken X-ray pictures without knowing it.

Photo: T. C. Hepworth.

FIG. 7.—A RADIOGRAPH OF A BOY'S HAND (AGED 12).
Compare with the mature hands in Figs. 8 and 9.

The first X-ray pictures of the hand were very imperfect, the shadow being ill-defined, and showing merely the rough outline of the member. They were what a photographer would call "out of focus." It is due to Mr. Herbert Jackson, of King's College, that a much more perfect form of tube speedily made its appearance. It is known as "the focus tube," and its construction is plainly shown in Fig. 6.

Photo: T. C. Hepworth.

FIG. 8.—A LADY'S HAND, WITH JEWELS, PHOTOGRAPHED.

Compare with the radiograph of the same hand in Fig 9.

At one end of the interior of the bulb is a concave disc of aluminium known as the *cathode plate*, which focuses the cathode rays at a point near the centre of the bulb. The *anode plate*, which can be seen near the centre of the little globe, takes the form of a square of platinum foil, placed at an angle of 45° a short distance beyond the focus of the cathode rays. The value of Mr. Jackson's work in producing this tube cannot be over-estimated, and although it has in other hands received various modifications, and improvements have naturally been made in the construction of tubes generally, we may look back upon this one as being the first which really gave perfect radiographs. Most of the illustrations which accompany this article were made by its aid.

In practice, the X-ray tube is held in a wooden stand with a kind of universal joint, so that its height, etc., can be easily adjusted by the turn of a few thumbscrews. I have found it convenient to use in connection with it glass uprights, fixed in wooden feet, each with a forked extremity, so that the wires connecting coil and tube may be insulated and kept out of harm's way. One of these glass posts can be seen in Fig. 5.

Crookes' experiments dealt with what took place inside the vacuum vessel, and so the matter rested until the year 1894, when Professor Lenard made experiments with a view to testing the action of the radiations *outside* the tube. He found that the radiations would penetrate a thin plate of the metal aluminium better than they would glass, and he made a tube with a kind of aluminium window for their emission. He it was who found that the radiations would affect a photographic plate much as light affects it, and it is said that this very important part of his work was the result of an accident.

It seems that he had on his laboratory table a box containing these plates, and when he afterwards came to use them

Photo: T. C. H[illegible]

FIG. 9. A RADIOGRAPH OF THE SAME HAND.

Note that the diamonds are transparent [illegible]

he found that when they were developed they blackened over just as if they had been exposed to light. He was careful to trace the source of the mischief, and he eventually found that the radiations from a Crookes tube would go through the wooden box and the black paper in which the plates were wrapped, and spoil them. Two years later Professor Röntgen, of Würzburg, repeated the experiments, and the happy thought occurred to him to place his hand over the covered photographic plate, when he found that flesh was almost transparent to the radiations, while bone was by contrast opaque. He thus achieved the remarkable feat of obtaining a picture—a shadow, really—of the skeleton of the living hand. The news of the wonder was flashed all over the civilised globe, and the discovery was immediately christened "the new photography." From what has been already explained it will be seen that this is a misnomer. Photography offers a means of recording the action of these rays, but it does nothing more. The discovery of this particular effect upon a photographic surface is due, as we have seen, to Lenard. Röntgen gave a human interest to it by interposing his hand between the plate and the Crookes tube, and has obtained the lion's share of the credit. We must not forget that without the work of our own distinguished countryman, Crookes, the discovery would not have been made. The name X-rays, indicating rays the nature of which is unknown, is the convenient term given to them by Professor Röntgen.

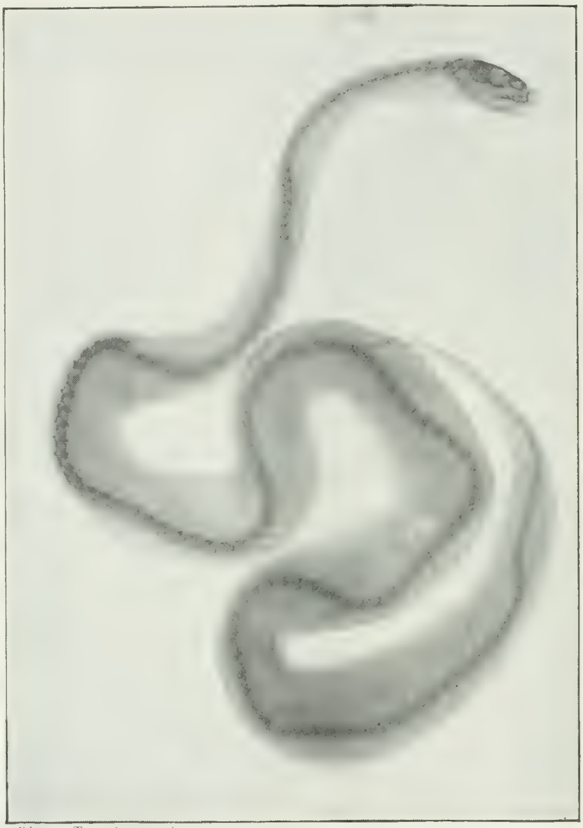


Photo: T. C. Hepworth.

FIG. 10.—A RADIOGRAPH OF THE ENGLISH ADDER, SHOWING BONES.
The shaded part is the skin and flesh.

Many theories have been suggested as to the nature of these radiations; but a consideration of them would hardly prove attractive, and would be somewhat outside the scope of this article. I have, in the introductory matter, shown clearly, I hope, that in the production of the X-rays no camera and no lens is employed. They would be quite useless; but it is necessary to point this out, because that unfortunate phrase of the enterprising journalists who first reported the discovery, "the new photography," made many persons believe that the usual photographic paraphernalia was employed in the work. What is really essential to the experimenter with the X-rays is a good induction coil, giving at least a four-inch spark, a battery or other source of electricity to feed the same, and

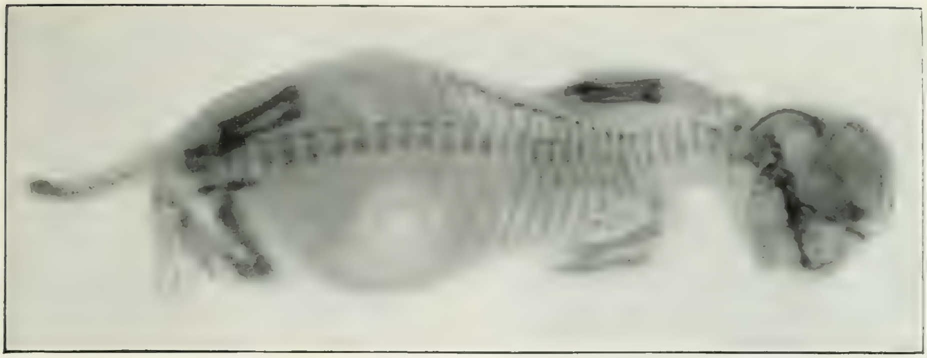


Photo: T. C. Hepworth.

FIG. 11.—A NEWLY BORN KITTEN UNDER THE X-RAYS.

Note that the bony framework is incomplete.

a Crookes tube on a jointed stand, so that it can be clamped in any required position. In Fig. 5 the whole of the apparatus is shown. In taking a radiograph—which is a convenient term to apply to a picture obtained by this means—say, of the hand, the photographic plate is wrapped in two or three perfectly opaque black envelopes, so that no light can get to it and spoil it. This plate is laid in its wrappings a few inches below the tube, and the hand is placed upon it. According to the efficiency of the apparatus, the picture can be taken with a few seconds' or a few minutes' exposure to the rays.

Many other misconceptions have been connected with X-rays besides that of associating them with the use of the camera. That they will have the effect of making hair grow on a bald head is simply nonsense. Others have asserted that they will remove hair rather than destroy it—and this is far from improbable—although the following report, clipped from an American paper, must be regarded as rather far-fetched. "A gentleman named Max Meyer lost half his whiskers at the New York electrical exhibition, and brought an action to recover £2,000 damages against the United States Electrical Supply Company, on the ground that they, with certain strange devices—the Röntgen rays, to wit—did utterly wither and destroy certain facial hirsute appendages belonging to him, the said Max Meyer, to the great detriment of his influence over the fair sex, and to the injury of the peace and dignity of the United States of America."

But, seriously, the X-rays have a very decided effect upon cuticle, producing a kind of burn, while in aggravated cases the action is much more severe. More than one ardent experimenter has lost his finger-nails in consequence of the continued action of the rays. A year back in the coroner's court it was shown that the injudicious application of the rays had resulted in very bad sores. On the other hand, it has been shown that in expert hands the rays have had a curative result in cases of lupus and cancer; and it has been asserted that in such diseases the X-ray tube is as reliable as the "light cure" now practised in many hospitals, and is far less expensive to instal and maintain.

Professor Röntgen's first experiment was with a Crookes tube covered with black paper, and he found that when he brought it near a card covered with the chemical known as barium-platino-cyanide the card became luminous. We shall presently see how the employment of such a compound has been turned to useful account. By means of an X-ray picture, or radiograph, we are able to see the entire bony structure of the human

hand, the foot, or any part of an animal, or of an entire animal, provided it is not too large to cover the photographic plate employed. Such pictures should be of

Photo: T. C. Hepworth.

FIG. 12.—A NEEDLE IN A CHILD'S KNEE: DISCOVERED BY THE X-RAYS.

extreme value to an anatomist or a zoologist. Let us take, for instance, the case of a fish, the setting up of whose bony skeleton—such as one may see at a museum—is a task of enormous difficulty which must consume many weary days. But by placing such a fish beneath the X-ray tube we are able, in less than a minute, to secure a perfectly correct picture of the bony framework of the creature, without resorting to dissection. The same may be said of almost any other small animal. In Fig. 10, for example, is shown the radiograph of an English adder, with every bone most beautifully traced by the action of the rays. Fig. 11 is the radiograph of a very young kitten. This picture shows in an interesting way that the bony structure of young animals is far from complete—a point which will be further illustrated presently.

As a general rule, we find that metals are opaque to these X-rays, but, as we have seen, Lenard discovered that aluminium was an exception. This applies only to very thin aluminium; when it is, say, more than a quarter of an inch in thickness it is opaque. Glass, although so transparent to light, is opaque to the X-rays. Coal, which is opaque to light, is transparent to the rays. Wood and paper behave in the same way. The page of illustrations of photographs and radiographs shows the curious differences between the action of light and these X-rays on various substances. Let us refer first to the reproductions of ordinary photographs taken with a camera. A number of common mineral substances are shown. Some of the subjects chosen are commonly regarded as very transparent—transparent, that is, to light; while others are opaque in the same light. These latter consist of lignite, graphite (commonly known as black lead), and cannel and anthracite coal.

And now let us look at the presentment of the same specimens as pictured by the X-rays. The beautifully clear quartz and rock crystal cast heavy shadows, showing that they are opaque to these rays; and we see that this is true of all the other substances, with the exception of mica. Then, taking the middle pair of rows—which, it should be particularly noted, contains only forms of carbon—we find that the lignite and the two specimens of coal are perfectly transparent, and that the graphite shows partial transparency. A purer sample would have proved to be quite transparent.

Glass, it will be seen, while not casting such a heavy shadow as quartz or rock crystal, is decidedly opaque. But the

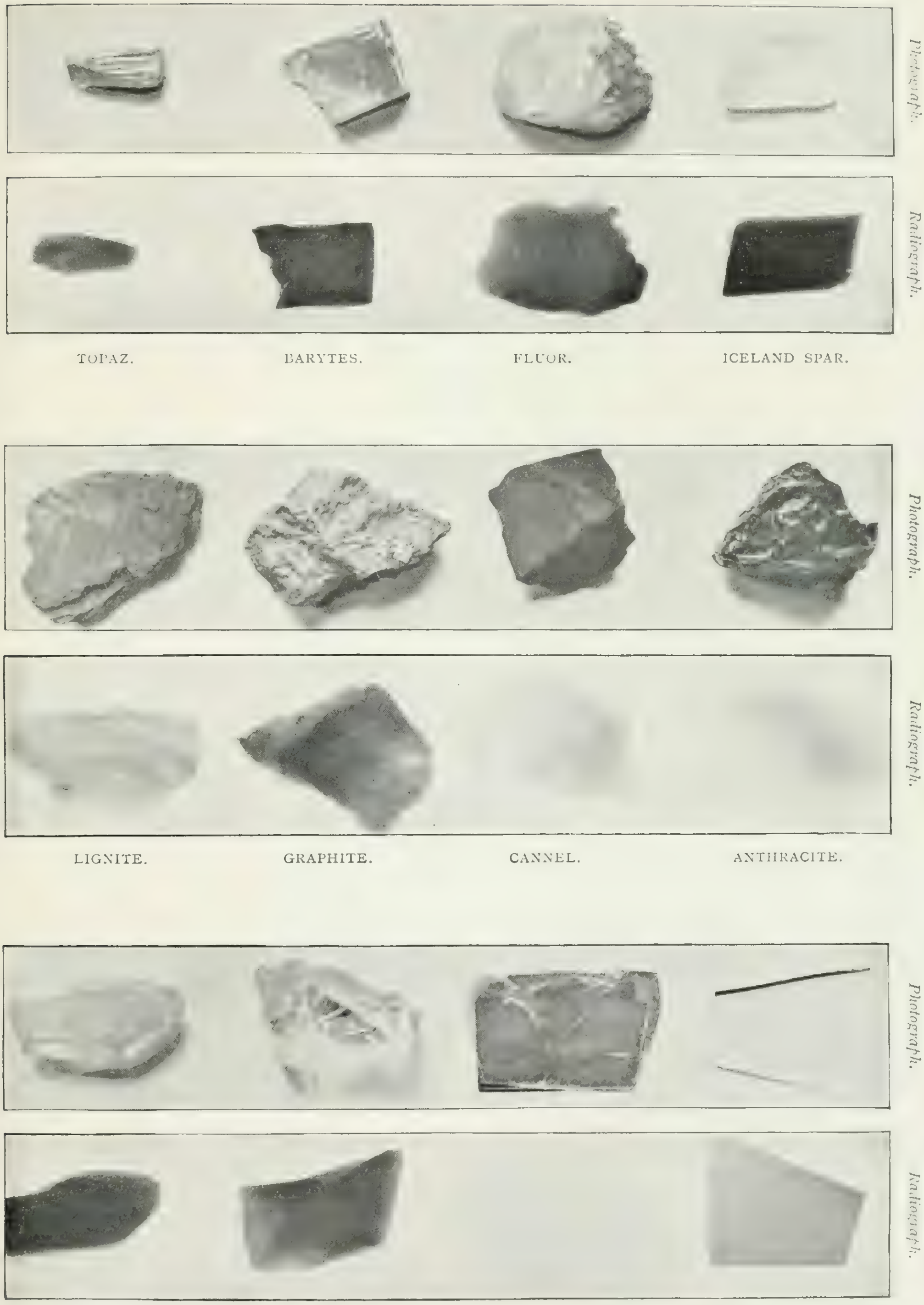


FIG. 13.—PHOTOGRAPHS AND RADIOGRAPHS: A CONTRAST.

A remarkable demonstration of the opacity and transparency of a number of substances.

diamond—which, as everyone knows, is merely crystallised carbon—is transparent to the rays, just like its near relation, coal; so that we have here an infallible means of finding out whether a gem purporting to be a diamond is the real thing or mere paste, and if jewellers had not a more ready means of testing such stones, the X-rays would come to their help. The photograph of a lady's hand covered with diamonds may be compared with a radiograph of the same hand which was taken on the same occasion (*see* Figs. 8 and 9).

We have just seen that carbon is transparent to the X-rays, and it may be assumed that printing-ink, which owes its blackness to carbon, is invisible to them. Thus we may place a book of several hundred pages over a coin, with the result that we get a distinct picture—or rather silhouette—of the coin, while the printed pages give ready passage to the rays. It is the same with writing-ink; and the stories, therefore, which have been published of the contents of sealed envelopes being revealed by these rays have been evolved from the inner consciousness of the authors. If, however, the ink, while wet, were dusted with metallic powder, the result would, of course, be different.

The value of the X-rays to surgery cannot well be over-estimated; and although their discovery is less than a decade old, it is no exaggeration to say that it has already had the effect of saving hundreds, if not thousands, of valuable lives. A foreign metallic body—such as a needle, pin, or a bullet—is readily detected, even if buried deep in the flesh. More than this, certain diseases of the bones can be detected; while the nature of a fracture, say, of one of the bones of the leg or of the arm can be readily seen.

Photo: T. C. Hepworth.

FIG. 14.—CRIPPLED BY A POM-POM SHELL.

Note the opaque piece of metal buried in the palm.

It is not necessary to employ a photographic plate in all such cases. We have already seen that the rays will cause certain substances to become luminous when brought within their influence. One of these substances is barium-platino-cyanide, and if we mix some of it with gum water, and spread it on a card, we shall possess a screen which will become luminous directly the rays—themselves quite invisible—fall upon it. Now, suppose that a man receives a bullet wound in the leg, and that the missile has taken an irregular course, so that its position cannot be detected with the probe. The X-ray tube is placed on one side of the leg in a dark room, and the screen is moved to and fro on the other side of the limb. The bony structure is plainly revealed, the shadow of the bullet is quickly found, and the surgeon is able to remove it with certainty.

Fig. 12 illustrates a case which came under my own immediate notice. A little girl had received an injury to her knee, but there was nothing apparent to guide

the doctor who was consulted as to its nature. He suggested poultices and bandages, accompanied by perfect rest. After a few weeks of this treatment the child, who was in perfect health save for a slight pain in the knee, was allowed to run about. Another doctor thought that a needle might have entered the flesh—but it was merely a suggestion. Three years afterwards I had an opportunity of examining the knee by means of the X-rays, and the radiograph which I took plainly showed that the second doctor was correct in his diagnosis. The needle can be plainly seen sticking up in the bone just below the knee-cap. By the aid of this guide the needle was removed the next day, thus avoiding possible future complications.

Complete X-ray apparatus now forms a most necessary part of the equipment of every field hospital in time of war. By its aid the surgeon can not only detect the exact position of a bullet—which, by the way, is often split up into fragments on entering the body—but he can see the amount of injury it has caused, and can thus quickly decide whether amputation of the limb is necessary, or the reverse. In the late Boer war the apparatus was in constant use, and the radiographs very plainly indicated whether the bullet received was a fair one, or whether it had been tampered with by the enemy with the object of causing a more serious wound. Such manipulated bullets were often erroneously called "explosive." In reality, the point of the nickel case was cut off, so that on impact the softer lead inside the bullet was forced out, making a terrible wound. If the bullet had really been explosive, it could hardly have wrought greater mischief.

Photo: T. C. Hepworth.

FIG. 15.—A WITHERED HAND.

A warning for mothers and nurses. Showing how one of the bones of the forearm has been dislocated.

Fig. 14 is the radiograph of what once was a human hand; but, sad to say, it bears little resemblance to one now. It belonged to a man who, while manipulating a pom-pom shell, had the misfortune to touch its cap with sufficient violence to cause it to explode, with the result that his thumb was blown off, with the best part of his middle finger, and the hand generally terribly lacerated. As the wound did not heal as favourably as was expected, he asked me to radiograph it, when it was found that part of the metallic casing of the shell had buried itself in the palm of the hand. This piece of metal is plainly to be seen in the radiograph as a dark patch, its presence being quite

unsuspected by the surgeons until the picture revealed it.

Another picture (Fig. 15), which looks very much like a bird's claw, is also the radiograph of a human hand, and its publication may have the effect of making good-natured people a little more careful in the way they romp with children. At the age of three or four years the person to whom this withered hand belongs was at play with his nursemaid, who lifted him up by the hands and swung him round and round, as one may often see nurses doing with their little charges. Something snapped, and that hand was no good to its owner from that time. It will be seen that one of the bones of the fore-arm has become detached from the wrist, and other injuries were caused which wrecked the member entirely and reduced it to the condition of a withered stump.

At birth a large portion of the bony structure is represented by cartilage, and the hand is not really complete, so far as its skeleton is concerned, until the age of nearly twenty years. This is well seen in Fig. 7, which is the radiograph of the hand of a boy of twelve. Compare this with Fig. 9, showing the lady's hand with the jewelled rings. In this latter picture, just below the diamond bracelet we can faintly see the two bones of the forearm—the *radius* and the *ulna*. Above the bracelet are the carpal or wrist bones, then the five metacarpal bones, which form the palm, and above these we have the phalanges, or finger bones, three to each finger and two to the thumb.

In the boy's hand (Fig. 7) we find that between the finger bones there are button-like processes, called *epiphyses*, from a Greek word meaning an "outgrowth," which are never seen in the adult hand. The transformation of cartilage into bone proceeds from two centres, and these buttons, at present detached, will, as the boy grows older, join the larger bones above. A case once came to my notice in which a boy of ten had the "buttons" joined to their neighbours prematurely—a circumstance which was doubtless due to the fact that this boy was a professional pianist, and that constant practice with his fingers had made his bones precocious. I suggested that this might be the case, and a radiograph confirmed my opinion.

The X-ray apparatus has been employed to detect certain kinds of adulteration in food. As most mineral substances are opaque to the rays, and vegetable compounds are transparent, and as the former are commonly used for the adulteration of the latter on account of their greater weight, the detection is not difficult. Among the sophistications implicated are sand and chalk in flour and chalk and alum in baking-powder. The rays have also been suggested as a test for the purity of coal; the greater the quantity of silica or pyrites present, the more opaque the product of the mine. The rays will also indicate the presence of gold in quartz, the metal giving a much darker shadow than its matrix.

A Frenchman suggested some time ago that printed matter made opaque by metallic dust might be made to furnish thousands of copies through the medium of the X-rays by being placed above a pile of the sensitive paper employed by photographers. The idea probably occurred to somebody who had no practical experience of either the X-rays or of photography.

THE STRUCTURE AND HABITS OF AN EARTHWORM.

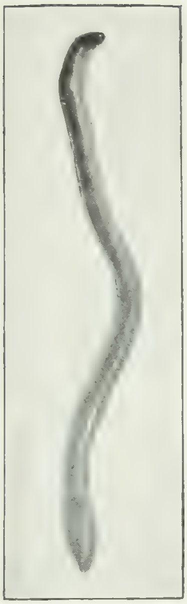


FIG. I.—AN EARTHWORM.
(*Lumbricus.*)

AN earthworm eating earth does not seem a very attractive subject either for investigation or amusement. The information which it yields to patient study and research is nevertheless endless. It is patent to everyone that worms live upon earth—not upon leaves, grasses, and so forth, as was formerly popularly supposed. Doubtless the origin of this mistaken idea was the fact that the earthworm, in burrowing into the soil, often carries leaves and parts of leaves with it. Still, if closely observed, it will be noticed that this is not so much from instinct or intention as from the force of circumstances. If it be remembered that on the surface of the skin numerous bristles (*setæ*) are seated, in pairs, at intervals on each ring of the body (Figs. 2 and 3), it will be evident that the worm in passing over the ground (especially if the atmosphere is moist) will entangle small leaves on these hook-like setæ, and as it enters the damp soil the leaf also will be carried down, until the friction of the surrounding earth of necessity loosens it from their hold. Although from observation we can prove that the earthworm lives upon earth, it must not be thought that mere earth is sufficient for its subsistence. Most persons will have noticed that in sandy or gravelly soils worms are rarely found in abundance; and, in fact, they are only numerous in rich alluvial soils, like meadows near a muddy river and old water-courses, in manure-heaps, and in all rich soils containing a large amount of more or less nutrient substances. This fact is soon proved by dissection. Let an earthworm be killed with chloroform (acetic acid or methylated spirit will do); then let it be cut upwards from the under or ventral side, beginning at the

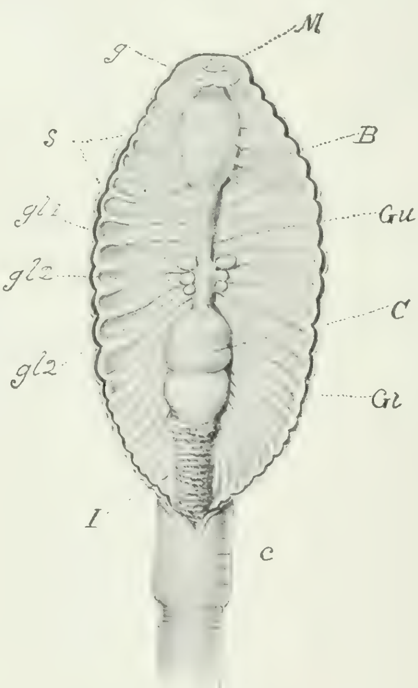


FIG. 2.—AN EARTHWORM DISSECTED FROM THE UPPER SIDE, SHOWING THE ALIMENTARY CANAL.

M. Mouth.
B. Buccal mass.
Gu. Gullet.
gl_1. Calciferous glands.
gl_2. Œsophageal glands.
C. Crop.
Gi. Gizzard.
I. Intestines.
c. Clitellum.
g. Cerebral ganglion.
s. Septa between segments.

anus, which may be known by having a more rounded termination than the head.

Next, place the worm on a flat piece of cork, and pin the sides down so as to expose the contents of the abdomen and intestines; the exact character of its food will then be clearly seen. Generally speaking, this muddy food substance consists entirely of moist earth, but occasionally, if closely observed, portions of organic nutrient matter will be noticed, especially if the substance is placed under the "inch power" of a microscope. The assimilative power of a worm may be tested by causing it to digest food containing some dye, such as carmine or madder. The following are the steps in this process:—

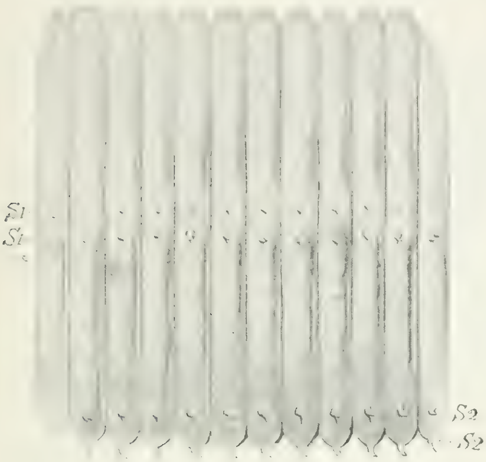


FIG. 3.—SEGMENTS OF AN EARTHWORM ENLARGED. *Note the two lateral rows of setæ (S_1 S_1) and the two vertical rows (S_2 S_2).*

Take about half a pint of common white sand; dust in the colour until the sand has acquired the right tint, then pour in a few teaspoonfuls of salad oil, or use a piece of lard about the size of a walnut. Place the jar on a hot plate, stir the sand until the grease is equally distributed through it, and then let the mixture cool. Now procure a few live worms, place them in the sand, which must have been previously rendered damp with water. After a few days it will be noticed that they have been living upon this prepared food, and if its use is continued long enough many of the organs and internal tissues will become partially coloured. This experiment is by no means cruel, as the minute particles of carmine simply deposit themselves in the tissues.

It is worthy of remark that worms must cause a large quantity of earth to pass through them before sufficient nourishment has been extracted—in fact, we might judge of the richness of any sample of soil from the number of worms found in it, taking for granted that the soil is damp, as they cannot (as we have seen) exist in dry situations. The swallowing of the soil is also of great assistance to the worm as it burrows into the ground; and as large quantities of earth are thereby removed and ejected behind, they are great friends to the farmer and gardener, constantly turning up the soil, and helping to make barren spots fertile. The old popular belief that worms bite the roots of plants is utterly untenable, as they are not possessed of teeth, having only a very powerful muscular gullet and alimentary canal, by the use of which they obtain and digest their food.

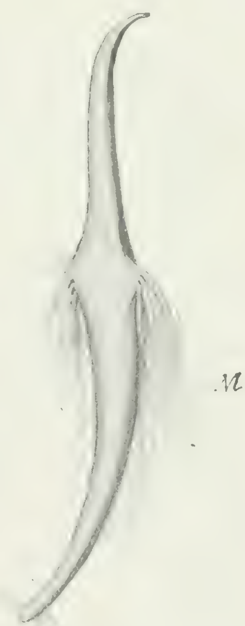


FIG. 4.—A SINGLE SETA. *M. The controlling muscle.*

The manner in which the earthworm swallows earth is curious. Its pharynx is extremely muscular (Fig. 2, *B*), and when the mouth is applied to the earth the movements of the walls of the former suck it in, and pass it onward to the

gullet and alimentary canal. Another point in their structure will strike even a casual observer—namely, that about the

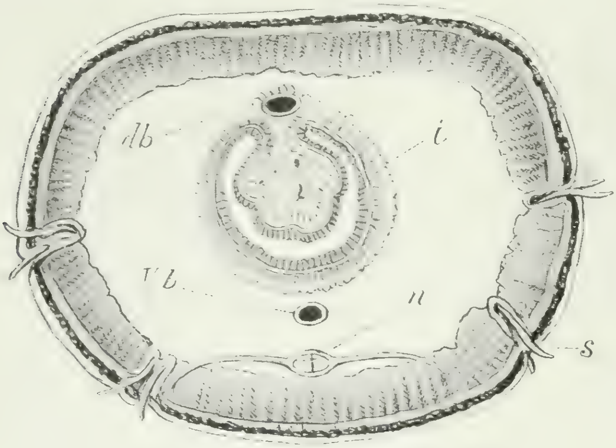


FIG. 5.—CROSS SECTION OF AN EARTHWORM.
(Modified from Marshall and Hurst).
i, intestine. db, dorsal blood-vessel. vb, ventral blood-vessel. n, nerve. s, seta.

twenty-ninth segment or ring of the body there is an enlargement (which generally extends to about seven segments below), having the appearance of an accidental injury to the worm; it is really not an injury, but an important part of its structure. Its tissues are glandular, their chief use being to assist the other tissues at the time of the reproduction of the species. This part of the body, called the *cingulum* or *clitellum* (Fig. 2), is entirely free from the setæ, and the segments are less prominent in their muscular character, which tends to give the appearance as before mentioned of a diseased or injured worm. In a well-grown worm there are about 350 segments or rings, although the general average is much less—namely, about 150. To observe the various systems of structure it is necessary to take another worm—in this case the larger the better. Kill it with chloroform, place it upon the loaded cork, and insert a pin through the first segment. Then with a sharp scalpel make an incision either along the belly or the back, from the mouth to the thirtieth segment; turn back the sides as far as possible, and fix them with pins; place in a shallow dissecting trough (a small white saucer would do), and cover with alcohol. Next with a fine camel-hair pencil brush away any undigested earth or other matter from the organs left exposed. Gradually, as the alcohol hardens the tissues (a few drops of bichromate of potash may be added) they become more apparent to view (Fig. 2). On observing the opened worm, the skin, muscular, digestive, and cir-

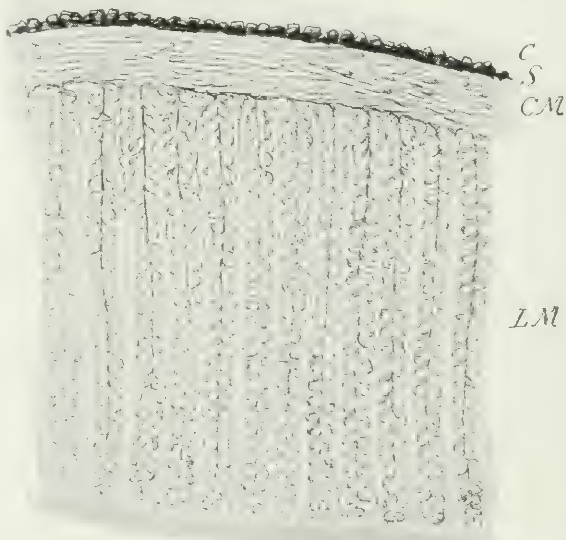


FIG. 6.—A PIECE OF THE BODY WALL SEEN IN FIG. 5, BUT MUCH ENLARGED.
C, cuticle. S, skin. CM, circular muscles. LM, longitudinal muscles cut across.

culatory systems are apparent, but the nervous, reproductive, and other systems are more obscure, and require the aid of a good microscope to work out their structure. The muscles of the pharynx will

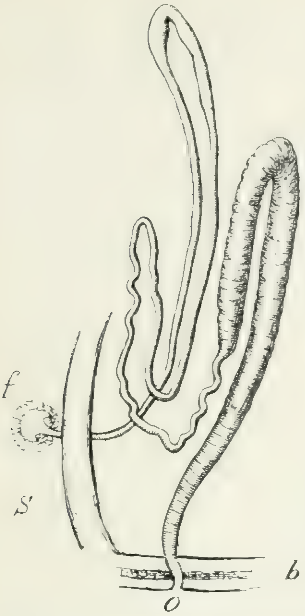


FIG. 7.—SEGMENTAL ORGAN.
(Nephridium).
f funnel.
o, orifice.
s, septum.
b, body wall.

be known by their strongly developed character (Fig. 2, *B*). The tegumentary (*i.e.* skin) tissue is so closely linked to the muscular system that in describing one we really—or at least partially—describe both. Each acts with and by the other, although the muscular is the more important.

On nearly every segment there are inserted on the body wall four pairs of setæ, or bristles (Figs. 3, 4, and 5), and these bristle-like bodies can be reproduced if injured in daily use. Some of the setæ will be found much larger than others, proving that there are old as well as recent formations. To thoroughly study the skin a transverse section must be made (Fig. 5). To do this well, the student ought first to stain the tissue with hæmatoxylin or picro-carmine, and then imbed it in gelatine or glue in the following manner :—

Soak the glue or gelatine in water until it is "jelly-like," then dissolve in glycerine and gum-water, equal parts, with the aid of heat. The piece of skin to be cut must be well soaked in water previous to its being imbedded in the mixture ; when well imbedded place the mass between two greased slips of glass, and allow the glue to dry. Then, when it is sufficiently dry, very thin sections may be easily cut with a sharp scalpel, the section having the appearance of that pictured (Fig. 5). The next illustration (Fig. 6) shows the transparent cuticle (*C*), the skin (*S*), and, thirdly, the muscular tissue, which is generally the thickest, consisting of a multitude of minute fibres crossing in all directions, those nearest the surface of the skin being parallel with the body (*C M*), and those that are more deeply seated running transversely (*L M*).

The muscular tunic, which extends the entire length of the worm, is at intervals constricted into rings, or "annulated." If a worm is held tightly between the fingers, the movement of these muscular rings will be self-evident, requiring a most severe pressure to prevent the progress or "wriggling" of the animal. The muscular tissue (Fig. 6) of an earthworm consists of simple contractile tissue, connected with stronger muscular fibres at points where the necessary power is required. In the first few rings of the body strong radiating muscular fibres

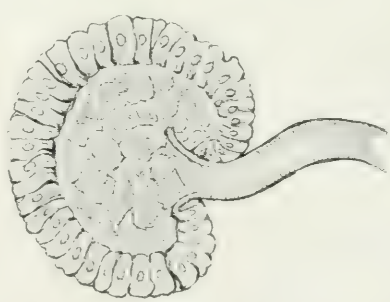


FIG. 8.—THE FUNNEL OF A *NEPHRIDIUM.*

diverge from the transverse muscles, thus immediately connecting the pharynx with the tegumentary or skin tissue. Another important use of the muscular tissue is to keep the setæ in their natural position, so that these hooks, or thorn-like bodies, may yield to pressure from the substance through which the

worm is forcing its way, but at the same time offer great resistance to any other substance meeting them from an opposite direction.

The next prominent feature to which

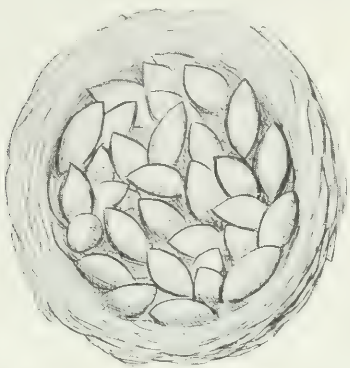


FIG. 9.—ENCYSTED GREGARINES. EVEN THE WORM HAS ITS PARASITE.

attention must be directed is the digestive system. The mouth of the earthworm is under a conical-shaped structure on the first segment of the body ; it lies in fleshy or muscular tissue that forms, as it were, lips. The movement seems to be the same as that in other parts of the muscular tunic. The pharynx, as already mentioned, is an exceedingly muscular organ, situated immediately below the mouth (Fig. 2, *B*), and extending from the second to the seventh segment. The back and sides are its most muscular parts.

As we trace the course of the alimentary canal (Fig. 2) we next come to the *œsophagus*, commencing at the eighth segment and continuing to the fifteenth or sixteenth. The "œsophagus" consists of a narrow but highly muscular tube, having an inner mucous lining or membrane. At the termination of the œsophagus, at the fifteenth or sixteenth segment, the digestive apparatus expands into a "crop." This is heart-shaped, and may be easily distinguished by its muscular appearance (Fig. 2, *C*), which is also horny to the touch, especially after treatment with alcohol. It occupies but little space, rarely taking up more than one or two segments of the body, and is found, as a rule, between the thirteenth and sixteenth segments. We now come to the so-called "gizzard," which is immediately behind the crop ; this occurs between the sixteenth and twentieth segments. Behind this again is the intestine (Fig. 2, *I*), which passes through the rest of the body to the anus (or vent) with but little alteration in its structure. In the tenth segment is a pair of sacs (the calciferous glands), which often contain calcareous matter, and which open into the œsophagus. Possibly the lime is useful in neutralising organic acids in the soil taken in as food. In the following two segments are other paired glands, which do not connect with the œsophageal tube, and their function is at present rather obscure. It may be added that the muscular coat of the intestine, though delicate in structure, seems to have great power in propelling the food onward.

In the earthworm there is a colourless perivisceral fluid which bathes the internal organs, but the true blood is coloured red, and is contained in a definite system of vessels, some of which pulsate rhythmically. The lateral vessels which connect the main trunk above the alimentary canal with that below are particularly well developed in segments 7 to 11, and are the so-called "hearts," which contract.

On examining the colourless fluid, it will be as well to allow a drop to partially evaporate under a thin glass circle laid upon a glass slide three inches by one. Drop one drop of crimson aniline dye close to the edge of the circle, when it will flow in by capillary action ; after an interval of ten minutes place the object in a wire clip and lay the slide in water.

After a short time the waste dye will pass off into the water, leaving the cells which float in it, some of which will

be found dyed. Place one drop of glycerine at the edge of the cover, and as the water evaporates it will supply its place; this takes about twelve hours. Seal the slide with indiarubber cement, giving two or three coatings, washing the surface before placing a fresh layer of cement; otherwise the glycerine will exude from the preparation.

This colourless fluid has communication with the exterior part of the body in two ways—first, through a series of pores (one of which occurs in every segment, with the exception of the first seven or eight), the other with the so-called segmental organs or *nephridia*. These organs communicate with the external part of the body by means of a long, tortuous tube, or canal, terminating at the inner end in an open, tunnel-like expansion of the tube, through which this white or perigastric fluid flows to the surface of the skin. That these pores have the power of absorbing fluids from the surrounding external matter is easily proved by touching the extremity (anus) of the worm with a few drops of any staining fluid, such as an aniline dye in water. The staining is thus made apparent. As the small absorbent vessels can easily be seen under the microscope, the corpuscles of this fluid—the size of which ranges from $\frac{1}{1000}$ to $\frac{1}{3000}$ of an inch—are most interesting, partaking as they do of many varied forms; if observed quickly after killing the worm, the amœboid movements of a few of the corpuscles is a sight worth seeing to any student of science.

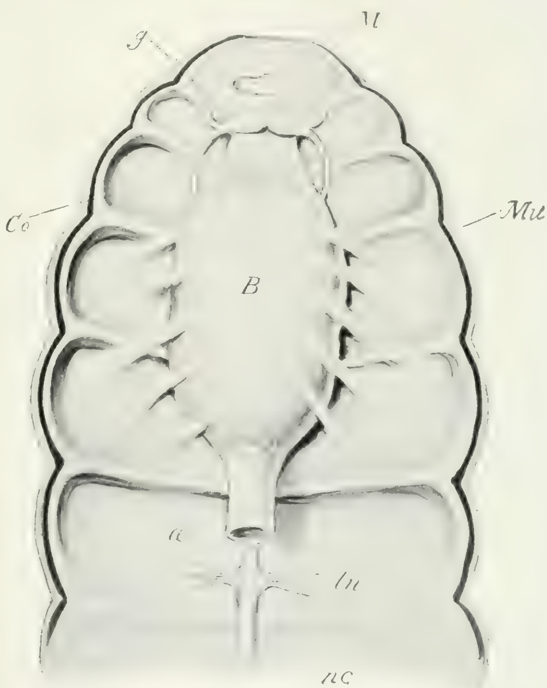


FIG 10.—THE ANTERIOR END OF THE EARTHWORM CUT OPEN AND EXPOSED TO VIEW.

M. Mouth.
B. Buccal mass.
Mu. Muscles controlling B.
œ. Œsophagus or gullet.
g. Cerebral ganglion.
Co. Commissure, one of a pair of nerves meeting below B.
nc. The nerve cord.
ln. Lateral nerves.

A remarkable and interesting form of life is found in all parts of the alimentary canal, though its minute bodies must not be confused with the blood corpuscles of the perigastric fluid. This is a parasite known as *Gregarina*, and is found especially in the intestinal canal (Fig. 9). The organisms occur as round, colourless sacs, containing minute oval bodies, which bear a remarkable resemblance to a species of diatom, called *Navicula*. Having thus partially explained the action and character of the colourless or perigastric fluid, it is necessary to return to the coloured (the vascular) fluid. It circulates in a series of vessels having three principal trunks (*see* Fig. 5): first, a dorsal vessel, already alluded to, running from the eighth segment to the length of the back of the animal; another called the sub-intestinal, running from the fourth or fifth segment; and a third, called the *sub-neural* or *ventral*, which lies beneath the ganglionic or nerve cord. The vessels on the back and under the intestine are connected by the so-called deep *commissural* (spinal) or central vessels in each segment of the body, with the exception of the first few front

segments. Those in connection with the stomach and gizzard—*i.e.* in the sixteenth to nineteenth segments—distribute capillary vessels to the fibrous structure of the stomach and gizzard.

Where these connecting vessels encircle the intestines they are closely attached to the wall of the intestine, and generally imbedded in the yellow, granular-like substance covering its surface, which, according to some authorities, has a biliary function. In the earthworm the superficial skin circulation of the blood, such as occurs in higher animals, is wanting. The "commissural" vessels give off various branches to the intestines, and both the supra-intestinal (dorsal) and the sub-neural vessels give off large branches to the muscular and other tissues of each segment. In the first seven segments of the body the larger vessels are wanting, their place being taken by a network of minor vessels. Behind the reproductive organs, if carefully thrown back, the commissural vessels will be found to be greatly dilated, forming about six to ten pairs of the so-called hearts, as described above.

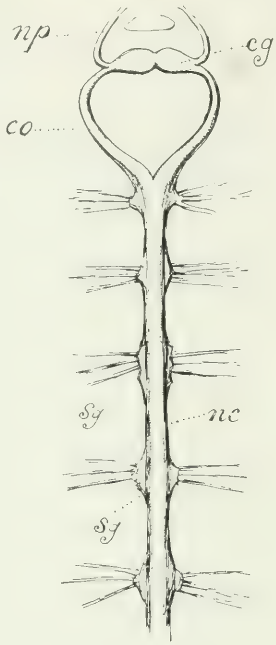


FIG. 11.—THE NERVOUS SYSTEM.

cg. Cerebral ganglion.
np. The projection over the mouth.
co. Commissure of the left side.
nc. Nerve cord.
sg. Ganglia repeated in each segment.

The nervous system of the worm consists of two *ganglia* closely united (Fig. 11), and situated in the third segment of the body, above the pharynx. From them spring two commissures, which unite below the alimentary canal to form a pair of cords, bearing ganglia in each segment. Each gives off from the sides three pairs of nerves, which again subdivide into filaments spreading through the muscular and other tissues. From the united ganglia, which are seated in the third segment, nerve-fibres are distributed to the lower part of the first segment, which thus tends to give the mouth its extreme degree of sensitiveness; in fact, so remarkable is this part of the body that some of our best authorities on the subject suggest that possibly other senses than that of touch exist in it, though in a rudimentary form.

Other minute glands occur in the anatomy of the earthworm, but in this brief outline any notice of their structure, and of those organs essential to the perpetuation of the species, is scarcely necessary.

These can be seen by killing a worm or worms, as occasion requires, with chloroform. It ought, however, to be remembered that a fresh dissection is always best; after the lapse of one day, even if kept in alcohol, the various structures lose their character to a certain extent, making it more difficult for the student to recognise each separate organ and tissue.

The only instruments necessary for the examination of a worm are a pair of long-bladed scissors, a fine scalpel, two needles, mounted in cedar handles—one bent at right angles, the other straight—pins, and a piece of cork loaded with sheet lead, which should cover the bottom, and turn up over the edge of the upper surface. If it is necessary to employ a lens, use one of long focus. One of the small hand-glasses used for examining photographs, or a watchmaker's eye-glass, will do.

NIAGARA FALLS

THE IMMENSE SUPPLY OF WATER POWER HERE AVAILABLE HAS BEEN TURNED TO ACCOUNT FOR GENERATING ELECTRICITY THE FIRST TRANSMISSION OF ELECTRICAL POWER FROM THIS SOURCE WAS MADE IN 1895

RIVERS: THEIR WORK AND CAÑON-MAKING.

EVERYBODY likes to look at a flowing river, and to watch the eddies and currents as they whirl floating things along, or wave the long weed on the bottom; but few people reflect upon the cause of the river, and what it does, or know the complicated work Nature has to perform before a drop of water runs down to the sea. As weeks of hot weather elapse, and the country becomes dried up, the river still flows onward; and if it is a large one, nearly the same quantity of water passes along each day. When the rain has fallen heavily for some time, how different is the scene! The river is full, or has overflowed its banks, and the water extends for miles; it is in tumultuous and rapid movement, and often trees are carried along, houses destroyed, and bridges broken, the power of the flood being enormous. The rain ceases, the flood falls, and the ordinary amount of quietly running water flows along as usual; but there has been plenty of mischief done, and if it be examined into carefully, some notion may be got about the way in which the valley was made in which the river flows. Two things may always be noticed:—

Photo: G. Wehrli, Kilchberg, Zurich.

FIG. I.—THE VILLAGE OF LAUTERBRUNNEN IN THE SWISS CANTON OF BERNE.

The walls of sandstone which rise on each side of the valley are from 1,000 to 1,600 feet high, and nearly perpendicular.

(1) Some stones, or gravel, or bits of rock, which formerly formed the sides of the river, have been removed, and may be found much lower down the stream towards the sea.

(2) The river has deepened its bed—that is to say, some of the bottom or floor has been scooped away, and the stones have been swept seawards.

In civilised countries, where much care is taken to protect the river-sides, these occurrences are not so well seen; but in other places there are extraordinary instances of the effects of river-floods to be observed. In some of the rivers of Bengal the scour is tremendous; and in one, stone and earth to the depth of 90 feet is removed every year from the river floor, and the channel is deepened by so much. All the accumulation there during the rainless months, when scourings are carried gently along, to collect in the holes and deeps, is washed out and carried to the sea. It is evident, then, that during flood-time solid substances forming part of the neighbourhood of a river and a portion of its bed are removed, and that the river fashions its channel out of the land. In the long run, the river removes the land to the sea and enlarges its channel, until a time comes when its power of doing all this diminishes—that is to say, when the water in the flood-time is not in great quantity, and its movement is not very rapid. This occurs when rivers grow old, for they are lively and full of work in their early days, when they scoop out their valleys and send the worn-off stone and mud to the seas. But in time the work is done, and the river, formerly wild, becomes tame, and does not even move enough stone and mud to the sea to keep its path straight.

Anybody who thinks over this matter will soon see that the power of a river depends upon the quantity of its water, and the pace at which it is moved along. Common-sense leads to the belief that the more rain that falls and can get into the river, and the greater the slope of the river bed towards the sea, the greater will be the effects of the moving water. If there is an unusually small quantity of rain, the floods will be less; and if, during ages, the river cuts its channel down nearer to sea-level than before, for miles and miles inland, there will be all the less slope and, consequently less rapid movement of the water. It is a question of water supply and readiness of running off that has to do with the story of the formation of a great river-valley. What is meant by a river-valley? A large river-valley opens at one end, either into the sea or into lakes; it is bounded at the sides by land higher than the river and sea or lake, and at the farther end, and near the source, the land is higher still. The streams flow down a slope of greater or less length, breadth, and pitch, and this sloping land, encircled on all sides but one—where the sea or lake may be—by hills, is called, in the language of science, a "catchment" or "hydrographical basin." The summits or tops of the hills are called the water-partings, and their sides and tops towards the river form the "watershed." We know that rain falling on the hills will run down them either towards one slope or another—the hills part the waters of valleys with rivers in them, and streams may be situated on each side. The sides of the hills down which water can run into a particular river are the watersheds of that river; and the great space between the distant hills is the catchment or water-catching basin.

A catchment-basin includes all the branches of the main river, and the land around them, up to the top of the hills, which act as water-parters. These basins are of different sizes, according to the distance of the high land, whence the river springs, from the sea into which it flows, and also according to the number of the branches and their lengths. The basin of the great river Mississippi, including the branches, occupies a large portion of North America; but that of the Thames, limited as it is on all sides

Photo J. S. Johnson, New York.

FIG. 2. NIAGARA FALLS IN WINTER.
Compare with the Coloured Plate.

but one by low hills, is very much smaller, but quite as perfect. In the instance of the "great river-system," as it is called, of the Mississippi, there are important branches which run into the main river. These may be said to have their own catchment-basins, and the main river is a sort of sea to them; but, really, all the side valleys that come at last down to the great plains through which the parent river wanders belong to the same system of drainage. These rivers drain the land of their catchment-basins, and there is some relation between the quantity of rain that falls on the surface of the basin in a year and that which is carried seaward by the streams in the same time.

A short journey will explain much about rivers and their valleys to anyone who can think a little. Going by rail to the West of England, the valley of the Thames is traversed from London by Reading and Oxford, and then an excursion will lead up the river by Lechlade to Cirencester. Some miles south of this last-mentioned town there is Thames Head, the springs of which we may assume to be the source of the Thames. During this journey the hills to the north and south of the flat plain, through which the river runs, are visible enough, and at last they come closer together. They are the watersheds. A gradual rise of the ground has occurred, for Oxford is higher above sea-level than London, and Thames Head than Oxford. Standing close to where (before the Thames and Severn Canal dried up the most distant springs) the river rises in Trewsbury Mead, the height above sea-level will be found to be about 330 feet.* But the summits of the hills there, from which water can get down towards the Thames, are about 500 feet above sea-level. These uplands get higher towards the north, and attain an altitude of from 718 to 1,084 feet, and thus some of the northern branches of the Thames have a higher watershed than the river into which they pour. The whole of these branches of the Thames are within its catchment-basin; and just on the other side of the hills are the catchment-basins of other rivers, such as the Severn, the Avon of Wilts, the Avon of Warwickshire, the Nen of Northampton, and the Ouse of Bedfordshire. On walking up the hills going west from the origin of the Thames the valley of the Severn is seen at last, hundreds of feet below, so that, within a few miles, several streams which flow eastward are rising at a height of more than 300 feet, whilst on the west there is the great plain with Gloucester on its river. The hills are the Cotswolds, and they are the water-partings of the Thames and its western branches and of the Severn. The length of the main valley of the Thames is computed at 120 miles to the Nore; and, as the most distant river-point is only 330 feet above sea-level, the slope of the valley is very slight. The river winds about, and has a total length of 210 miles. If we consider that the highest hills of the Cotswolds

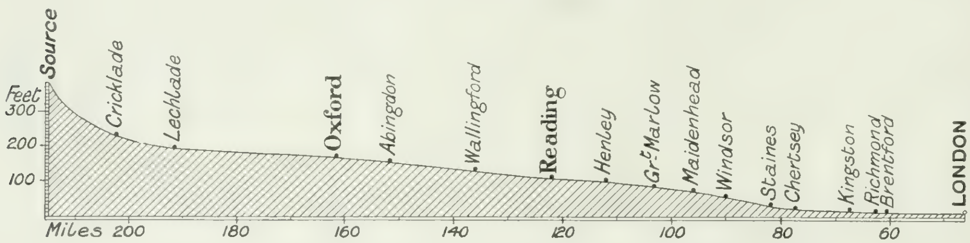


FIG. 3.—DIAGRAMMATIC REPRESENTATION OF THE FALL OF THE THAMES, FROM ITS SOURCE TO LONDON.

* These details are taken from Phillips's "Geology of Oxford and the Thames Valley," a most charming book.

—such as Cleeve and Edge Hill—form part of the watershed, then the extreme height is 1,084 feet, down which water pours. The tide comes up the Thames, but not so far as formerly, for it is stopped by the weir and lock at Teddington. Hence, in all calculations, the Thames may be said to end at Kingston. Above Kingston the catchment-basin, when measured, has an area of 3,675 square miles, and of course some of the rain that falls on that surface gets to the river, and carries down soluble matter and the wreck of the land. In uncultivated countries, where the land around the sources of a river is mountainous, the stream may rise some thousands of feet above the level of the sea, and then its course may be divided, according to the nature of the river's bed or bottom. In mountainous districts rivers arise in torrents and wild, roaring streams, which tumble the water over rocks and amidst boulders. These are the torrent portions. Then, as the edge of the high land is passed, and the river enters the open country, a fall often takes place, and waterfalls are seen (Figs. 4, 5, and 6). Then comes the less quickly flowing part of the river, where it curves here and there, running often sluggishly; and this is in the midst of plains or valley-bottom land, which is liable to be flooded by any unusual outpour of water. These portions of the river's valley are called flood-plains. Finally, the river may enter the sea by one or more channels. In the latter case a "delta"—so called from its resemblance to the Greek letter Δ—is formed. The Ganges, the Nile, and the Mississippi all have deltas. Frequently the land in the vicinity of the sea-coast is flat, the fall of the land seawards is not so great, and the current of the river becomes sluggish. The result is that, instead of carrying the alluvial matter brought thus far into its course right into the sea, much of it is deposited at the river mouth. These rich alluvial deposits frequently contain specimens of the plants and animals—or their remains—belonging to the countries through which the course of the river lies. Thus examination of the delta at a river's mouth will not

Photo: G. Wehrli, Kilchberg, Zurich.

FIG. 4. THE ROSENLAUI FALLS.

Situated in a fir-clad valley of the Reichenbach, Switzerland.

only enlighten us as to the geological formation of these countries, but with regard to their flora and fauna as well.

Some rivers arise from streams of water that flow out from beneath glaciers on high mountains, and a few appear to commence in mountain lakes; but even in these instances the idea of the catchment-basin holds good. One thing is very certain, although it is opposed to a curious popular error, and that is that comparatively a very small quantity of the water issues forth from the earth at the origin or source of the river. It has been thought that the springs of the commencing river contribute principally to its supply of water, but this is a fallacy. Thus the quantity of water that flows from the Thames Head and thereabouts is 500 cubic feet in a minute, and this is a very small proportion to the 1,380,000,000 gallons that pass daily by Kingston. Many tributaries, of course, go to swell the amount, but their source-springs do not contribute much; and indeed, in one remarkable instance, the branch of the river sends less water into the main stream than it gets from the source-springs. This has been shown to be the case with the River Churn, which rises, west of Cirencester, at a height of 680 or 700 feet above the sea. There are several sources, and one well known and visited is that of the Seven Wells. There beautiful, clear, pure water bursts up briskly through natural cracks in the solid rock, and forms a small rivulet. In the dry autumn of 1859 the late Mr. Simpson, the engineer, made some estimates about the amount of water supplied by the springs to the Churn, and by this to the Thames. He found that 11 cubic feet of water was discharged from the spring-head in a minute, and that a quarter of a mile down the stream 31 cubic feet was passing along in a minute, and that at a mile 73 cubic feet went along at the same time. Hence water got into the stream from some other source than the spring-head. At five and a half miles no less than 320 cubic feet passed over the bed of the river in a minute, so that there was a very considerable increase. But, farther on,

Photo: G. Wehrli, Kilchberg, Zurich.

FIG. 5.—THE LOWER REICHENBACH FALLS.

These falls lie to the south of the village of Meiringen, Switzerland.

Photo: G. Wehrli, Kilchberg, Zurich.

FIG. 6. THE DIESBACH FALL.

This is one of the most picturesque of Swiss waterfalls. It is situated on the River Linth, close to Betschwanden.

the river, instead of increasing in its amount of water, began to get smaller, and when it was fourteen and a half miles from its source it poured only 10 cubic feet along in a minute. The water increased in the river up to a certain amount, and then gradually fell off to less than that poured in first of all. This was accounted for upon a principle which requires attention. The first part of the stream poured along a bed of clay, down through which water cannot pass; but the second part passed over a hard rock called *oolite*, which is full of cracks and crevices, and the water went into these instead of passing along. The first kind of bed (that of clay) is said to be impervious—water cannot soak into it and be lost—and the second, the oolite, is porous, and full of cracks. Hence clay and suchlike layers of earth or strata are called *impermeable*, and limestone, chalk, gravel, and sand in layers are called *permeable* strata. These terms must be remembered, for the arrangement of the divers kinds of layers of earth in a valley has an important bearing upon the behaviour of rivers.

But how was it that the water increased as it flowed over the impermeable clay? The answer is that rain-water, sinking down into the soil, passed through a pervious subsoil, till it came into contact with the dense clay, and ran on its surface, subterraneously, until it flowed out into the stream, which had cut its bed lower than the top of the clay. There was then a supply of small springs on the top of the clay, for the water collected there during wet weather, and discharged so many cubic feet in a day during dry weather until all was exhausted. Lower down the stream, the rain-water passed into the porous strata lower than the bed of the river, and did not add to it in any way. In some countries the upper layers of the earth are so very permeable by water that rivers of any size and length cannot exist. The constant and average amount of water in a river is due to springs at its head and along its course, wherever impermeable strata are capped by permeable.

If a river were to run in the midst of parched stony land, without cracks or crevices in the solid earth, it would be a torrent in wet weather, and be represented by a dry watercourse in the dry season. On the other hand, if the stream passes along a very permeable soil, with equally permeable rock beneath, it will not carry all its water to the sea; and, indeed, some streams disappear altogether under the circumstances. Floods are produced by water running off the impermeable strata in excess.

Understanding, then, the relation of springs to the perpetual flow of a river, and of excess of rain to its floods, it is necessary to consider the amount of rain that gets to a river, and how far the streams may be said to drain and wear the catchment-basin. The quantity of rain that falls day by day can be calculated by measuring the amount which collects in a rain-gauge, and thus so many inches are said to have poured down in a year. These gauges are placed in several parts of the catchment-basin; and it is found that different quantities of rain fall in different parts of the country surrounded by the water-parting hills. A calculation is made, after several years' observations have been completed, regarding the average "fall" over the whole space during each year, and then it is stated that a certain number of inches of rain fall on the catchment-basin during a twelvemonth. This number varies in different valleys and in different counties of England, and it is hardly the same in any part of the world. Nevertheless, the quantity of rain that falls within the carrying-off power of a river can be estimated year by year. About 3 feet of

rain (36 inches) falls on the high lands around the head of the valley of the Thames. Suppose that on all the space inclosed by the watershed of the Thames above Kingston (3,675 square miles) 28 inches of rain fell in the year—for that would be about the mean quantity—how much of this would come off by the river in the same time? The quantity of water that comes down in dry, in wet weather, and in flood-time during the year has been calculated, but it does not amount to more than one-third part of the rain that falls in the twelvemonth. What becomes of the other two-thirds? An explanation of the small quantity really carried away by the river can be found, by observing the effects of rain in different parts of the valley through which the river runs. After a smart shower on a clay soil—an impermeable stratum—much water runs off into ditches and brooks, and goes down to the rivulet and then to the river; but a good deal is left, having wetted the soil and formed little pools and puddles. All this is dried up and does not go to the river; it is evaporated, and passes up into the air in the form of invisible vapour. Some of the rain does sink in, for clay is found to be always wet a few feet down. Plants take up a good deal of the rain, and build it up into their structures; but most of this moisture thus received is evaporated from the leaves. A different state of things happens on a chalk, limestone, or gravel soil, these being permeable strata. The rain sinks in and passes down through the earth to collect upon the top of the first layer of clay; but little runs off into streams to get to the river, much is evaporated, some goes to the support of vegetation, and a portion comes forth as spring water into

Photo: Taunt & Co., Oxford.

FIG. 7.—THAMES HEAD, IN WINTER.

The spring running.

the river. As there are more of these strata in the valley of the Thames than of the dense, impervious kinds, more rain sinks into the earth than runs off suddenly by the river. A great proportion, indeed, of the rain never comes near the river at all, but sinks down far beneath it for hundreds of feet into the earth.

There is a remarkable thing to be noticed about the River Thames and the River Severn. If it rains much for a few days, the Thames will get very full of water, but will not overflow its banks; but the Severn and its branches to the north and west soon overflow and produce floods. Why is this? In the catchment-basin of the Thames above Kingston there are more permeable strata near the surface of the earth than impermeable ones. Consequently, a vast quantity of rain-water sinks into the earth, and either passes far below the river or is laid up in store for springs. There are about 2,424 square miles of such strata out of the 3,675 square miles of the whole catchment-basin. The basin of the Severn has a preponderance of hard strata which will not let the water in, so it has to run over them, and the result is flood.

This is interesting, and it shows the influence of the events of the geological ages, when the strata were made, upon our present rivers and water supply. The rain-water that goes into the permeable strata soaks them to a great depth, for on making cuttings or tunnels through chalk, for instance, it is always found wet. The water is stored up in the strata, and it may be disposed of by nature in several ways. Some is evaporated from the dry crust of the surface soil, and some flows deeper and deeper until it collects at last on the top of a stratum down through which it cannot pass. This happens when a deep, dense stratum or a layer of clay underlies the porous one containing the water. If there is the least tilt of the impermeable and lower stratum, the water will move in its direction. This statement holds good whether the thickness of the upper porous layers is a few feet or a mile. In the instance of the lower impervious layer being very deep, of course none of the water can get into the river; but when the layer is near to the surface there is a chance of the water pouring out gradually as a spring, which will flow into a river.

Thus the rain-water that falls on the chalk hills to the south of London sinks in and goes down for hundreds of feet, to be stored up and tapped by very deep wells. None of it goes to the river. But the rain that falls on Highgate, Hampstead, and Harrow goes through a few feet of gravel and sand only, and then comes to a clay which stops it. Consequently on several sides of those hills there are springs just where the clay and gravel join and "crop out," as the geologist expresses it, on the side of the hill.

Probably about one-third part of the rain that falls on the catchment-basin runs off by the river during the year, and one-sixth of this is derived from springs.

The catchment-basin is worn by water action above and below ground. The streams, torrents, and large rivers wear their beds and banks by the friction of the water rushing along, assisted by the stones it rolls; and the underground waters carry off particles of rock to the river, and leave spaces which form subterraneous caverns and lead to the formation of underground rivers.

Thus the rain carries off the surface of the valley inch by inch, and widens, deepens, and lengthens it.

Time, a constant flow of water sufficiently swift to move stones rapidly on the bed of the river, and occasional floods —which bear great masses of rock, boulders, and gravel along, wearing everything in their way—were necessary to the formation of many of the deep valleys which are situated in the torrent and cascade portions of some rivers. Rain

FIG. 8.—BIRD'S-EYE VIEW OF THE CAÑONS OF COLORADO.

and the ordinary wear of the surface are less important agents. Such gorges as that which leads from the Falls of Niagara to Lake Ontario in Canada have been worn by the action of running water and moving stone, which has cut down the solid rock for miles in length, nearly 400 yards in breadth, and from 200 to 300 feet in depth. The sides of the gorge are steep, and the wearing water comes down the river, and not from springs at the sides. The falls, where a vast volume of water pours over rock, are gradually wearing their foundations away, and some day or other they will have cut down the rocky bed over which they pour, and will thus increase the length of the gorge. Probably the falls have receded from the lake into which their resulting streams run, seven miles off, and the slit-like valley has thus been excavated. In this instance the constant supply of water comes from Lake Erie, higher up the country than the falls.

The wearing down of the most extraordinary gorges in the world, and the cutting of their vast chasms out of solid rock, have been produced by similar causes, but the action of rain on the surrounding country is very slight, the country being now comparatively rainless. The cañons of the western territories of the United States—in some instances a mile in depth, in deep shade at the bottom, and at one time traversed by a comparatively quiet stream, and at others by a downward rush of tumultuous waters, carrying large masses of stone along—are often scores of miles in length, and resemble cracks in the earth rather than watercourses. The country in many places is so intersected by these cañons that the drainage of the surface on which very little rain falls is so rapid that great sterility results ; but the water that may come into these long channels at the sides is of little importance. They drain important mountain regions far off, and snow and glacier ice supply a quantity of water which, passing down along a very considerable slope, has a great velocity and wearing power. The wearing of the sides from the ordinary agents of denudation, and the very small quantity of rain, is inconsiderable in relation to the depth of the gorges. But things were different when they were first formed and cut down ; there was then a greater water supply, and in some instances movements in the earth assisted the cutting down of the rocks and the removal of the resulting gravel and stone.

It was formerly a country of great lakes, which were not much above the level of the sea. The land was upheaved gradually, and the lakes—then many hundreds of feet above their former level—began to pour through natural creeks and along the line of old streams to the sea. The drainage of the catchment-basins in which the lakes were was very great, and it flowed into these vast receptacles of water, so that an enormous supply of water power was ready to act on the rapid slope to the sea ; moreover, the evaporation from the latter supplied snow to the mountains, and this fed the lakes again. Cataracts were formed, and their floor was worn backwards. The lakes became dry as the cañons were perfected, and these deep, V-shaped chasms remain as evidence of a long lapse of time and of the work of the constant rush of water and stones on solid granite and limestone and sandstone rocks, without the concurrent action of rain and the ordinary denuding agents of valleys.

The cañons of the Colorado are magnificent beyond description, and the river system drains an area of vast extent. That is to say, the catchment-basin is about the third in point of extent in North America, those of the Mississippi and Columbia being the largest. The Grand Cañon is much longer than the valley of the Thames, for it exists as a gorge for over 200 miles, and its depth is not less than 4,000 feet. Two rivers—the Grand and Green Rivers

—unite in the eastern part of Utah, and a vast waterflow occurs. The amount of water is great, the pitch of the bed is rapid, and thus a great source of power is at hand, possibly equal to that of the flow of the Falls of Niagara. The rivers meet in a narrow gorge, more than 2,000 feet deep, and then the cañons begin. The first is called Cataract Cañon, and the descent of the river is rapid. The velocity of the water and stone rolled down is equal to that of a railway train. At the foot of the cañon the sides come very close, and for seven miles the water goes along at the rate of forty miles an hour. The rocks cut through by this stream show all the geology of the country. Sometimes the face of the precipitous sides of the cañon is red, from a sandstone without a seam; or they may be of limestone—pink, brown, grey, slate-tint, and vermilion in colour, and polished to perfection. In the Grand Cañon the highest sides are nearly 7,000 feet above the stream, but they are only perpendicular for about 3,000 feet, where, indeed, the gloomy chasm is often but a few hundreds of feet wide. Above that the sides slope off by a series of cliffs to the level of the surrounding country; and if the world lasts long enough, and a greater rainfall should come, a deep and wide valley will exist there some day or other. The remains of dwellings of prehistoric man, with which the neighbourhood abounds, speak of an age when this now sterile region was able to support human life on a large scale. The aborigines living in some of the towns of Arizona are probably the descendants of a once powerful race who at one time held possession.

On looking at a map on which the cañons are traced, or at a bird's-eye view of the country in which they are found (Fig. 8), one is struck with their position in regard to some mountains, and to their occasional rather zigzag course. Some cañons form long lines close to the flank of the mountains, and just where the hills spring from the plain, and then they start off right away, and only bend here and there. The impression is given to the mind that some cracks in the earth had occurred to determine the path of the future watercourse, which in time was to become a cañon. But if this were so, the crack did not displace or let down one side of the country around, so as to produce what geologists call a *fault*, for the levels of the layers of earth or strata, seen on each side of the cañons, correspond in a remarkable manner. It is generally found that wherever limestone is the top layer of the country, or nearly so, the wandering of the cañon is great. Limestone is so easily worn by water that if a hard piece resists for awhile the effects of a stream, the water will erode on one side of it, and then the course is diverted from the previous direction. Once made, the crack is deepened, and then other strata beneath it are worn down.

The word "cañon" is applied in America to any gorge through which water flows; but, properly speaking, the term should be restricted to the long chasms with steep sides situated in nearly rainless regions.

A PIECE OF SPONGE.

FAMILIAR as is an ordinary piece of sponge, yet few people are able to give any rational account of what it is in reality. The dictionary definition, "A soft, porous substance, remarkable for sucking up water," hints only at one of its qualities, common to a number of objects; as, for example, a piece of blotting-paper, which in its way is equally bibulous. Even to the minds of most well-educated persons the true nature of the former substance is far from clear. The common and current notion that sponges are marine plants, or that they in some way or other appertain to the sea-weeds, would seem to have its foundation in the general aspect of the objects themselves: their light, fibrous, vegetable-like texture, the well-known fact that they are procured from the sea-bottom; and their occasional exhibition in museums and shop-windows attached — stalked or rooted — to a portion of rock or other substance suggest this, and it is easy to understand how they come to be looked upon as plants. Nor is this to be wondered at, seeing that for a long time naturalists and those who had made a special study of the sponge tribe were by no means agreed as to their nature. Some would have them to be plants, others that they were animals of a low order, and so they were bandied about in the systems of classification, at one time finding a place in the animal, at another in the vegetable, kingdom. Nay, more — at length a learned German hit upon the plan of placing them, along with several other lowly organisms of equally uncertain nature, in a separate group intermediate between plants and animals. Thus one would suppose the perplexity of the case got rid of; but not so— "confusion" became "worse confounded,' until imagination had run riot on the subject of some phases of their development; and, once fallen into the hands of theorists, poor sponge has been made the basis of a history and plan of creation.

Let us place before us an ordinary bit of sponge taken from the dressing table, or purchased from the basket of the street hawker. Perhaps, the coarser the specimen is, the better will it be for our purpose—namely, that of examining and illustrating its structural peculiarities.

The physical properties of such a piece of sponge are few, but manifest and characteristic. We observe that its colour varies from pale amber to a deep, occasionally ruddy, brown. Bleached sponges, deprived of much of their natural colour by chemical means * and given a characteristic yellow tint, are often to be seen in shops.

This process, although it may improve the appearance of the darker coloured varieties in the eyes of some people, is not resorted to in the case of valuable specimens, which are merely treated with weak acid in order to remove foreign calcareous matter. This matter, if left in, might prove detrimental to users of the sponge. There seems to be little doubt but that the fibres are weakened to some extent if bleaching is carried out.

The best varieties of Turkey sponge, as is well known, are soft and velvety to the touch. Squeeze one, and it shrinks in dimension; the grasp unloosed, it springs back to its original form: it is thus resilient and elastic to a degree. Its lightness is a most appreciable quality. A morsel placed on the tongue yields no

* By the use of permanganate of potash, followed by treatment with hydrochloric acid and hyposulphite of soda.

distinct taste; chewed or pressed between the teeth, it seems fibrous or stringy, or coarse and gritty from the sand and foreign particles retained within it, according to the sort of sponge. Cast it into water; at first it floats freely, but by degrees absorbs the fluid, settles down, and ultimately sinks. It is thus remarkably absorbent, and, as the phrase runs, "is porous as a sponge." As a body, nevertheless, it is opaque, though thin slices transmit light, like shavings of horn, while a flood of light passes through the openings and vacant spaces, whatsoever be the direction of the cut. Apply flame to a small portion; it does not burn brightly, but frizzles, singes, or chars, according to the intensity of the heat. If this is great, a pellicle of metallic lustre, or light fragment of charcoal-like matter, is left. Meantime there arises from it a strong, disagreeable odour, very similar to that produced by the imperfect burning of hair. Neither cold nor boiling water, alcohol, ether, ammonia, nor, indeed, most chemical reagents, reduce sponge-fibre to a soluble consistence; even the strongest acids and alkalis act upon it only slowly, so that in this respect it is a very resistant body.

By permission of Messrs. Cresswell Bros. & Schmitt.

FIG. I.—DIVING FOR SPONGES IN THE MEDITERRANEAN

This diver is using modern apparatus.

As regards its own chemical composition, analysis shows that silk and sponge scarcely differ in composition. A peculiar substance called "fibroin" enters largely into the constitution of the sponge of commerce. Neither this substance, nor anything in the slightest degree resembling it, is found in any plant.

We thus learn that sponge, in its physical properties alone, might be of a fibrous, vegetable nature, but chemically it exhibits phenomena and composition akin to those attributed to animal bodies.

In its mechanical construction, an examination of the specimen before us shows that the sponge combines the

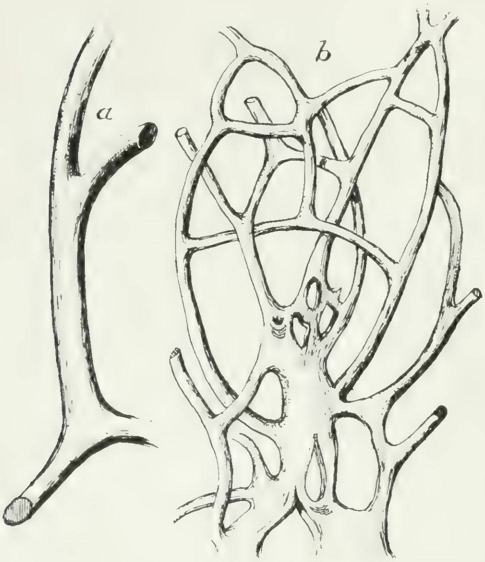


FIG. 2.—SPONGE FIBRE AS SEEN UNDER THE MICROSCOPE.

a, a single fibre, highly magnified
b, a network of fibre (after Claus), magnified.

maximum of lightness, delicacy, and strength, with an architecture wonderfully adapted to fulfil a combination of purposes.

The much vaunted skill of our engineers may here take a lesson from Mother Nature in one of her humblest efforts.

Under the microscope a thin slice of the sponge consists alone of a meshwork of yellowish, solid, interlacing filaments or threads (Fig. 2). These are exceedingly delicate in some examples of the best Turkey sponge, averaging $\frac{1}{900}$ of an inch in diameter; in others they are much coarser, and of a greater calibre. Usually they are almost uniform in thickness, though sometimes, as Professor Quekett first observed, a fibre double the size of the rest is met with. These bigger fibres possess great interest, for they not unfrequently contain rudiments of minute flinty, needle-shaped bodies, termed *spicules*. With the exception mentioned, these flinty needles are absent in the sponges of commerce; but these bodies—of most extraordinarily varied figure and size—nevertheless, play an important part in the economy of some sponges (Fig. 3).

For tenuity, elegance, and relative strength, a spider's web is a marvel; and hardly less wonderful for length of fibre, lightness, and close packing is the cocoon of the silkworm. Combine the material and principles of these two, and there results the netted, permeable, water-sucking object—our common toilet-sponge.

The further building up of the loose network of fibres is not a matter of mere indifference, for although in sponges there is an almost endless variety of patterns, both as to their exterior and interior conformation, yet all are formed so as to permit the passage of water in certain directions.

In the fine and brown Turkey sponges (*Spongia officinalis* and *S. Zimocca*, Figs. 4 and 5) the top is drilled with large

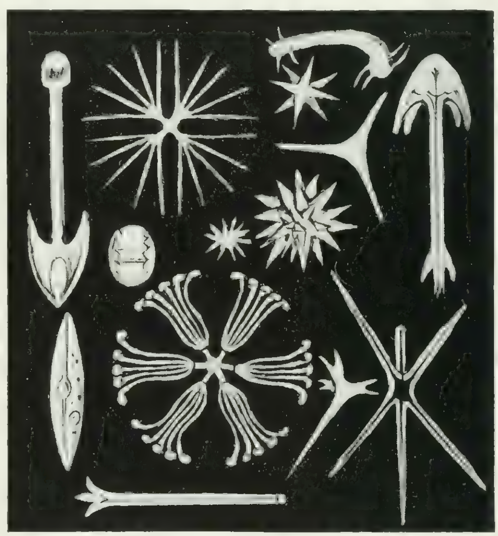


FIG. 3.—VARIOUS SPONGE SPICULES.

holes or *oscules*, which chiefly lead directly downwards. On the other hand, the outside, as seen in the "cup" (Fig. 6),

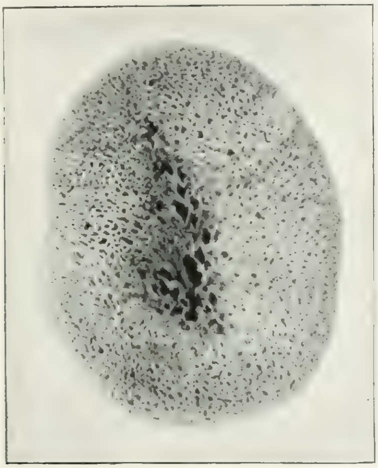


FIG. 4.—A FINE TURKEY CUP SPONGE.
(SPONGIA OFFICINALIS.)
Showing oscules opening into the cavity.

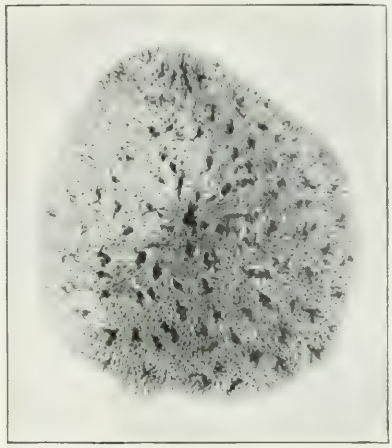


FIG. 5.—A BROWN TURKEY SPONGE.
(SPONGIA ZIMMOCA.)
Upper side showing oscules.

is perforated by openings like so many pin-holes, or "pores," and these more often lead obliquely down and inwards.

In the bath or honeycomb sponge of trade (*Hippospongia equina*), the dome-shaped expanse is not only rougher than in the Turkey, but what gives rise to the technical name is the honeycomb-like dispersion, throughout the entire surface, of large, gaping apertures (Fig. 7). The channels into which these openings lead correspond to the "cup" of the Turkey, for in their walls the pores and oscules are to be found. It is this feature which separates the genus *Hippospongia* from *Spongia*. In this sort of sponge is also well seen a peculiarity less apparent in other species. Long, jagged peaks of the felt substance stand out at all points, and they particularly surround the large apertures, even forming a crater-like rim, bending over or partially obscuring the hole. Sometimes in specimens of *Hippospongia* from the Bahamas the channels give rise to tubular prolongations of the sponge.

FIG. 6.—A FINE TURKEY CUP SPONGE ON A ROCK.
Side view, showing pores.

This must not be confounded, however, with upgrowth round the oscules, for in some species a very pretty appearance is thus caused, the fibre shooting forth in unusually long, free extremities of a tubular or a pencil or brush-like character (Fig. 8), to which the name of "peludo" (hair) is given in the localities where these sponges occur; in the trade they are known as "silky grass."

From what we have thus learned regarding the structure of the sponge before us, we can now understand how a dry sponge so greedily sucks up water,

and so readily parts with it on pressure. Passages everywhere communicating,

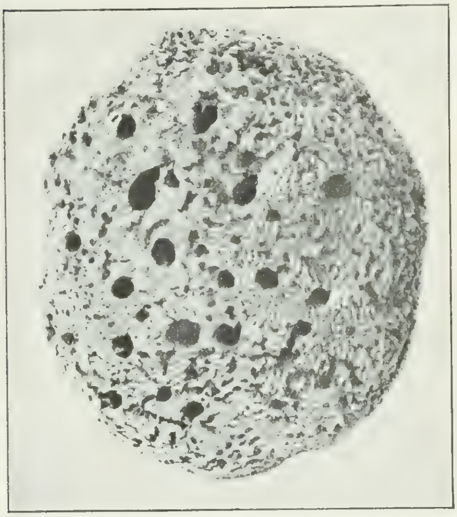


FIG. 7.—A TYPICAL MEDITERRANEAN HONEYCOMB SPONGE (*HIPPOSPONGIA EQUINA*).

whose walls are made up of a close network of the finest fibre, permit and cause the fluid to rise by the "capillary attraction" of the physicist, until the substance is perfectly saturated; capillary attraction, as Faraday has well put it, being "that kind of action or attraction which makes two things that don't dissolve in each other still hold together"; and, indeed, where the interstices are extremely narrow, the fluid is forced on by the weight of the mass behind. The currents of water in the live sponge proceed from a different cause. Again, the minuteness, flexibility, toughness, and withal durability, of the tissue, together produce those qualities for which the sponge-substance is valuable and an every-day necessity.

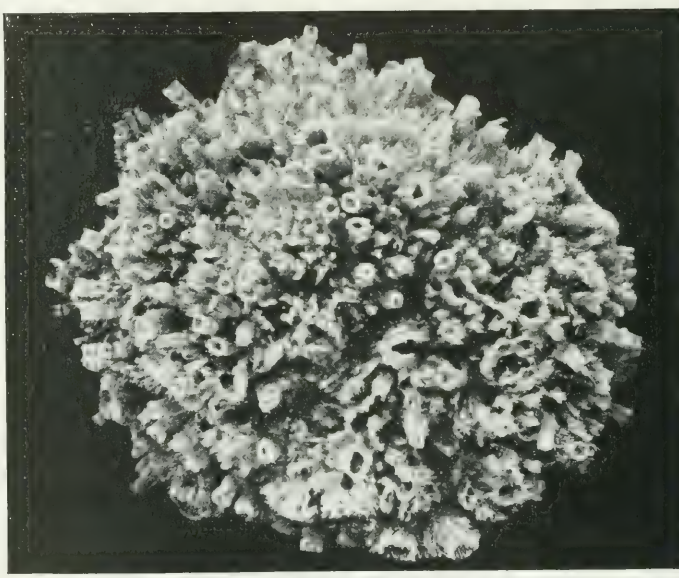


FIG. 8.—A GRASS "PELUDO" SPONGE, SOMETIMES CALLED "SILKY GRASS."

Notice the long, curious outgrowths of this West Indian form.

But hitherto the dried sponge, which, after all, is only the skeleton, has engaged our attention. The living object and its economy carry with them life-problems of exceeding interest—an epitome of all those functions performed by the complicated organs in our own body, but here reduced to the utmost simplicity. Other generalisations, moreover, hang thereby.

To see the sponge in life we must now go to an aquarium, or seek for some shady rock-pool on the coast where specimens of our smaller native sponges cover the stones, or cling to the roots in the tangle. It would still be better could we examine one from the "fishing-grounds" in the Mediterranean.

Incidentally it may here be mentioned that, in collecting living sponges in the East, a fleet of one-masted, lug-sailed boats (*caiques*), manned by crew and divers, are occupied during the whole of the summer months (Fig. 1). The old-fashioned Mediterranean diver goes down naked, with an open net around

the waist, and carries a stone attached to a rope. Without instruments, he tears

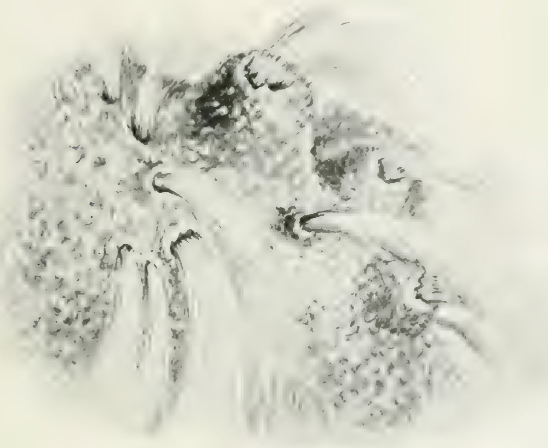


FIG. 9.—THE SPONGE AT WORK.

The currents of water passing from the "oscules," as seen under the microscope.

the sponges from the rocks, throws them into the net, and, giving the signal, is hauled up.

Many Greek divers, among their own islands or on the African coast, use a modern diving-dress and knife or spear to cut away the sponges from their attachment; but, as the air-tube often fouls, they will throw this aside. The naked men remain down from 1 to $1\frac{1}{2}$ minutes. They descend to the depth of 8 to 12 fathoms, but expert divers will go down even 40 fathoms. Usually, from a dozen to thirty sponges reward a plunge. The best forms are said to flourish in the deep water; but this is more likely to be from being less disturbed and picked off. Certain London merchants now buy direct from the boats prepare the produce by drying, and simply pack in cases for transmission. A fishing village is often strewn with sponges lying out to dry, giving the neighbourhood a strange but characteristic appearance.

When first obtained from the sea, the sponge of commerce is a vastly different thing from that in our shops. It then is comparatively heavy, and presents a dark bluish, slimy appearance, with an odour of shell-fish. Few holes are visible, most of them seemingly being blocked up with the glutinous substance. Then the process of what technically is called "taking the milk out" is proceeded with, prior to sun-drying: for if the soft matter be left in putrefaction results. The process adopted by some of our English merchants is secret, and the precise means in use among the fishers is not clearly understood except by the initiated. At all events, by a squeeze and a wrench, or stamping under foot, a milky or semi-transparent, sticky,

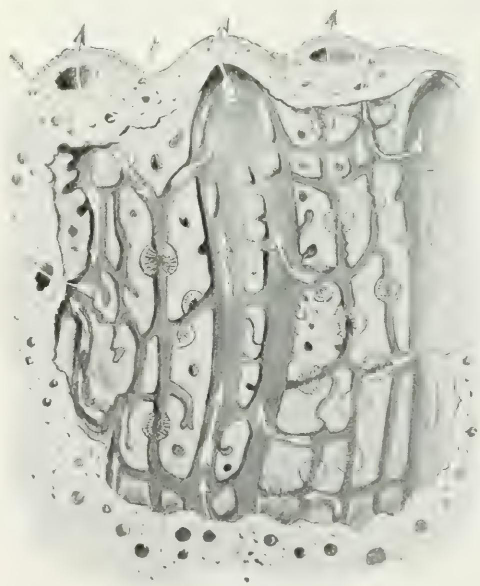


FIG. 10.—DIAGRAMMATIC SECTION OF A PIECE OF SPONGE, SHOWING THE DIRECTION OF THE CURRENTS.

The arrows show how the water enters by the small pores, to pass out by the large "oscules." Food is thus brought to the cells which line the channels.

gelatinous substance is extracted. The sand and grit in the new-dried sponge are

foreign residue, either partially subservient to preparation, or surreptitiously introduced to add weight and increase the money value of the article as sold by weight.

The slimy substance or fleshy material above mentioned is the soft part of the living animal—or congeries of animals, for such they prove to be. This jelly—so delicate that it runs off like milk from the fibrous skeleton when death has occurred, or occasionally dries like glue on the fibre—everywhere lines the fibrous structure, and forms a surrounding film. In appearance and composition it is much the same as the white of egg. For long, its nature was held to be problematical, even among the master-minds of zoologists, and all experiments and opinions elicited nothing more than that it was a torpid mass of doubtful vitality. However, after the labours of a host of scientific investigators, its animality, and many other strange particulars, are now proved beyond a doubt. Examine attentively, say, a sponge in the aquarium. When under favourable circumstances for observation, the following particulars may be verified.

First, then, currents of water run in through the *small* pores (Fig. 6), and, traversing throughout the sponge-material, at length return and make their exit in streams through the *large* holes or oscules (Figs. 4 and 5). In sponges growing near low-water mark, as the tide recedes, all the orifices close, again to open and admit the water as this rises and covers the object. This fact can be witnessed in the sponges on our rocky shores ; and if a small living piece is put under the microscope in a watch-glass, with sea-water, to which is added a little carmine, the currents of particles are most convincing (Figs. 9 and 10). To the living sponge it matters not whether the surrounding water is perfectly still or in movement, for the currents of water permeating its substance continue all the same.

The water-currents are due to "ciliary motion." This vital action is the same which drives upwards the phlegm or irritating particles from our own lungs and throat, and which also sends whirling about to and fro the young oyster before it has settled down to its sedentary shelly existence. Besides, ciliary action subserves many other purposes throughout the animal economy. "Cilia" (their name being derived from the Latin for eyelash) are hair-like filaments or threads of extreme tenuity (no more than $\frac{1}{4000}$ to $\frac{1}{2000}$ of an inch in length), which keep undulating like a field of corn blown by the wind. They thus set up a current, or push along the fluid or other movable particles on the surface, in a uniform direction. The cilia, however, in the sponge are not promiscuously dispersed, but are confined to minute, deeply situated chambers or dilatations of the canals (Fig. 11). Giving ourselves no concern with technical terms other than regarding them as "ciliary chambers," we nevertheless find they possess considerable interest. These chambers, of very diminutive capacity, are encircled with a closely set series of flask-shaped cells or "bladders," sunk in the gelatinous, fleshy substance, a single lash-like cilium protruding from each (Fig. 11). In this respect there is analogy to the cilia in our own frame, which are attached to little scale-like bodies—scurf being scales of this nature, but without cilia.

But these flask-shaped cells of the sponge are in reality so many microscopical animals, each endowed with a vitality of its own, and in structure precisely identical with some of the singular, free-moving animalcules of our ponds and ditches; so that the sponge in a certain sense is a colony of individuals aggregated and held together by the white-of-egg-like substance and the skeleton, be it of fibres or spicules or both.

Arranged in the chambers like bottles in a bin (Fig. 11), these sponge-cells freely ply their cilia, and hence comes it that the sea-water is drawn through the porous substance. That it only enters at the small holes and issues at the big ones is dependent on the special direction given by the moving cilia. It possibly may also be that by alone entering the minute pores the chances of the passages becoming blocked up is reduced to the minimum. But withal, strange — even living —objects do betimes get drawn in and entangled, queer pranks arising thereby.

Reviewing now what we have learned from the bit of sponge before us, we find, viewing our facts in their simplest aspect, that a sponge may be compared to a fibro-gelatinous colander, grosser particles being retained and absorbed as nutriment, the passing fluid carrying off waste material, etc. Professor Huxley, often as happy in simile as pungent in repartee, compared the sponge to "a kind of subaqueous city, where the people are arranged about the streets and roads in such a manner that each can easily appropriate his food from the water as it passes along."

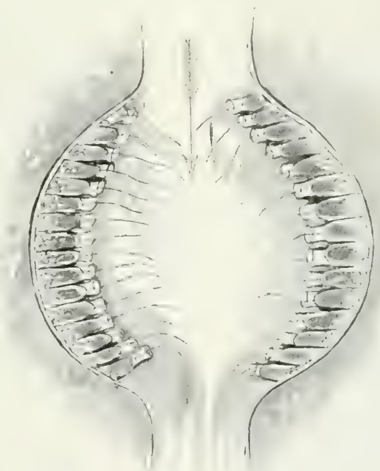


FIG. 11.—A "CHAMBER," WITH "CILIA" AND BOTTLE-SHAPED CELLS.

The movements of these "cilia" set up the currents of water referred to.

Both as a mechanical and physiological apparatus, sponge simplicity contrasts with the complications met with among the higher animals. Of blood there is none, neither intricate mechanism of heart, arteries, and suchlike; still, the function of circulation is effectually performed, and nourishment-bearing fluid—water—brought into proximity with every part of the frame. Lungs or gills are dispensed with, yet the equivalent of respiration takes place by the constant renewal of the sea-water; for oxygen is absorbed, and carbonic acid given off. Then, as to the function of secretion, and the excretion or giving off of waste products: skin, with its sweat-glands and other accessories, and the kidneys to boot, are not brought into requisition, yet much refuse is eliminated. Absorption of food and digestion takes place, and yet there is no stomach, gut, or glands. The food-particles come haphazard with the current, and here and there get entangled among the jelly body-substance, which takes up such matter as may be solvent and allows the remainder to pass away. It may here be asked: Is there any nervous influence guiding and controlling selection of the atoms, acting on the general contraction of the slimy flesh or movement of cilia? Some cells have been discovered amongst those which live in the gelatinous matrix, and are parted at one end, to which a sensory function has been ascribed.

It remains still for something to be said concerning reproduction, growth, and development, to complete the life-history of a sponge. Herein lies a wide field for generalisation and speculation. Accordingly, those naturalists gifted with powers of imagination have constructed a system of animal transformation which sets Swift's satire on the labours of the professors in the Lagado Academy of Projectors completely in the shade.

It is a matter of every-day knowledge that plants may be propagated by cuttings, by grafting, by buds, by bulbs, or by seeds. Now, among the lowest forms of animals, the sponges included, processes of reproduction analogous to those of vegetables are not of infrequent occurrence. Unfortunately, a complete history of the development of the common sponge (*Spongia officinalis*) has not yet been followed out in detail; but a study of other forms will, in many respects, give us a fair idea of what in the main is prevalent among the group.

There is a kind of sponge which grows in the fresh water, and is to be found, among other places throughout the country, on the floating timber in the Commercial Docks at Rotherhithe, at Cookham on the Thames, and in some of the canals in the neighbourhood of London. The living sponge, therefore, can easily be obtained and examined by anyone desirous of making himself practically acquainted with the water-circulation, development, etc. In this, the river sponge (*Spongilla fluviatilis*), there is no network of horny fibre, but, instead, a meshwork of the needle-shaped *spicules*. For our illustrations of propagation this does not negative the general conclusions.

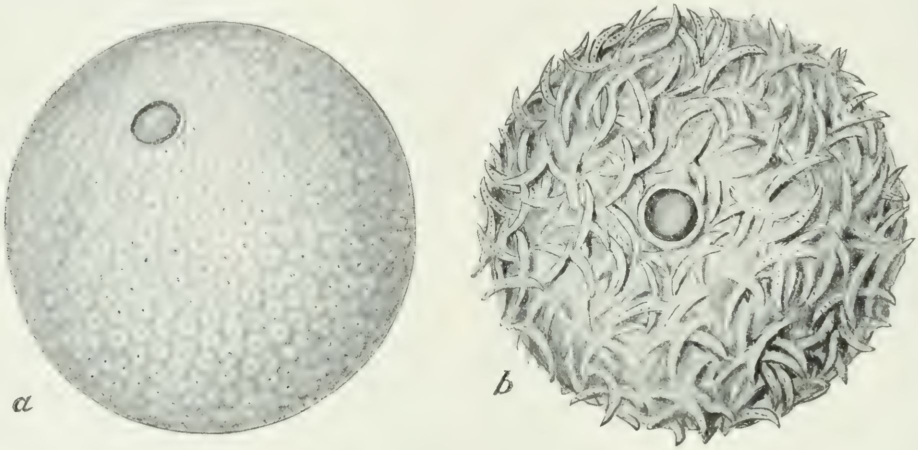


FIG. 12.—GEMMULES OF THE FRESH-WATER SPONGE (*SPONGILLA FLUVIATILIS*).
(a) The natural condition of the gemmule. (b) The gemmule treated with nitric acid to show its spicular coat. (Very highly magnified.)

If a mass of this be torn asunder or cut in pieces, or, as occasionally happens, spontaneously divides, each of the parts will maintain its independent existence, and flourish as a separate individual or specimen. This would be equivalent to the "cuttings" of plants, though it implies something more. Sponges have been artificially increased in this way. Again, two *Spongillæ* growing apart may approach, and when brought into contact will fuse into one, so that afterwards no line of demarcation can be distinguished. This to a certain extent represents the operation of "grafting," as practised by horticulturists. Still further, various sponges may send forth a process or body comparable to a bud, which, when thrown off, lives, grows, and ultimately propagates its species, as would a plant under similar circumstances. But there is another modified process akin to this, which takes place by a kind of winter-bud, to all intents and purposes representing propagation in plants by bulbs. In this, towards the autumn months, a number of the sponge-particles seem to fuse together and form a horny or flinty shell (Fig. 12.), of a round, oval, or occasionally elongated shape, but with an opening, and containing within a number of granular cells;

These remain quite inactive through the winter; the spongilla itself meantime having died down. As spring comes round, however, the cells, heretofore dormant, manifest vitality, and, escaping from the shell by the opening, give rise by the ordinary process of growth to new sponges.

The foregoing phases of reproduction are regarded as modifications of budding; but there is still another mode, where eggs are hatched within the body of the parent.

In this case certain of the marine sponges, about midsummer, develop in their interior a multitude of little cells or bladder-shaped structures — the eggs (Fig. 13, 1) — which are either scattered throughout the tissue or aggregated in heaps within a sac. These ova, except in very rare cases, are naked cells capable of independent locomotion in the matrix of the sponge, after the manner of an amœba. A process of segmentation takes place; that is to say, each egg cell divides into two spherical cells. These cells, or little spheres, again divide into four (Fig. 13, 2); and at a further stage, subdivide into eight; still again subdividing, until at length, in a large number of species—especially the calcareous sponges — a hollow, oval embryo is the result (Fig. 13, 3 and 4). This, later on, develops a covering of cilia of extreme tenuity (Fig. 13, 5), and these by their lashing movement drive the larval sponge freely about in the water. Presently the ciliated cells are pushed in, as it were, just as one may push in part of a soft indiarubber ball (Fig. 13, 6). The cup-like depression is gradually covered in by the growth of the edges until only a small hole is left (Fig. 13, 7). Thus transformed, the larval sac settles down and fastens itself by the root-cells to pebble or rock, as the case may be; and the cilia are then lost. The fixed embryo hereafter increases in bulk, begins to spread out a gelatinous substance at its root, and the free conical end shows a

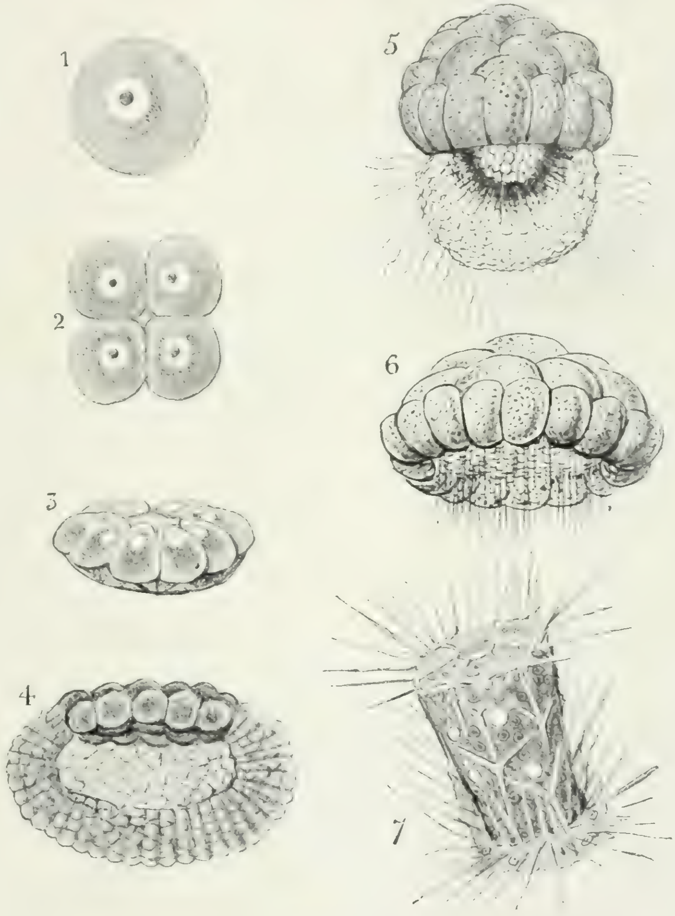


FIG. 13.—THE DEVELOPMENT OF A CALCAREOUS SPONGE.
(After F. E. Schultz.)

1. The egg.
2. The egg: division into four cells.
3 & 4. The egg: further cell division.
5. The embryo develops cilia.
6. The ciliated cells are pushed in.
7. The embryo gives up roaming and settles down to its rocky bed.

depression. Then, as the growth proceeds, the latter becomes a hole—one of the future exits of water currents—whilst smaller-sized pores of ingress become faintly visible. The true sponge character now becomes manifest, perforations proceed apace, and the structural organisation already referred to ultimately gives completeness to the compound animality of the sponge.

Such are the changes undergone from egg to adult in certain of the sponge tribe. This group, as a whole, with a structure and life-history comparatively simple in its kind, withal possesses, as has been shown, a many-phased mode of development, seen also in the segmentation in higher animals. The changes undergone from egg to larval stage, indeed, often impart such resemblances to those of animals high in the scale of being, that they form an important piece of evidence in favour of the theory of evolution.

The sponges of commerce are derived from the Mediterranean, from Florida, the Bahamas, and Cuba. Mediterranean sponges are chiefly represented by the fine Turkey (*Spongia officinalis* var. *mollissima*), the brown Turkey (*S. Zimocca*), and the honeycomb (*Hippospongia equina*).

The best kinds of the so-called Turkey sponges are said to be obtained at Mandruca and at Benghazi, on the Tripoli coast. There is also a good sort got from the islands of Cyprus and Crete. The Grecian Archipelago yields a fair supply, but their quality is by no means so good as those of the first-mentioned districts. The Florida, Cuba, and Bahama sponges, owing to the high price of the Mediterranean article, are now very largely used.

Paradoxical it may sound, but, nevertheless, London, it is said, is the cheapest, and at the same time the dearest market —or rather, strictly speaking, commands the maximum market rate—for certain qualities of sponges. This arises from our metropolis forming the focus of the trade; and with quantity there necessarily will be gluts, and, temporarily, depression of value. On the other hand, a higher price is freely paid here for the rare and better sorts than elsewhere can be obtained.

As housewives and families know to their inconvenience and disappointment, a seaside village, all amongst fishers, is not the place in which to be well served with fish, every catch being hurried off to the town by rail. Thus, with sponges, the finest forms come direct to England, where the nations buy. One of the better qualities, however, in a cleaned condition, finds its way to France. A commoner sort of the Turkey sponge is sent on to Southern Germany and Austria, by way of Trieste. Russia receives only the very poorest, coarsest sorts; while America, with her own sponge-producing banks, purchases the superior articles in the English market. These data would seem to afford a proof that ablution in Britain is, after all, of more frequent occurrence than our sanitary boards may admit.

In the wholesale market at present, Bahama and Turkey sponges range from 8d. to 50s. the pound weight, according to quality, but the prices as retailed are ruled by a somewhat arbitrary standard. A good-sized piece of a common West Indian sort may be had for a penny, or a few pence, whilst another kind of the Turkey sponge, no larger than one can easily grasp and squeeze in the closed fist, will cost from 5s. to 10s. or more; the same a little larger, proportionably to its bulk, brings even a much higher sum. The why and the wherefore of this inequality in value will be readily comprehended from what has already been said as to the differences in fineness and elasticity of the fibre. But, moreover, the prices of sponges of all kinds have enormously increased within the last few years.

Fine Turkey sponges are assorted as follows :—

A.—FINE TURKEY SPONGES.

1.—CUPS.
2.—SOLIDS.
3.—FLATS.

CUPS, as the name implies, are usually cup-shaped, and their fibre is of varying degrees of softness and elasticity. Though small in size, these sponges fetch the highest prices.

SOLIDS vary a good deal in both shape and quality of fibre. Sometimes they are rounded, sometimes flattened ; at other times they exhibit a modified cup shape.

FLATS are of the shape indicated by the name. Or they may be thin-walled "cups" cut up. Sponges such as these are employed in surgical work, and to wash the fine varnish on carriages.

B.—BROWN TURKEY SPONGES.

The best of these are utilised for toilet purposes, and the coarser grades put to various commercial uses.

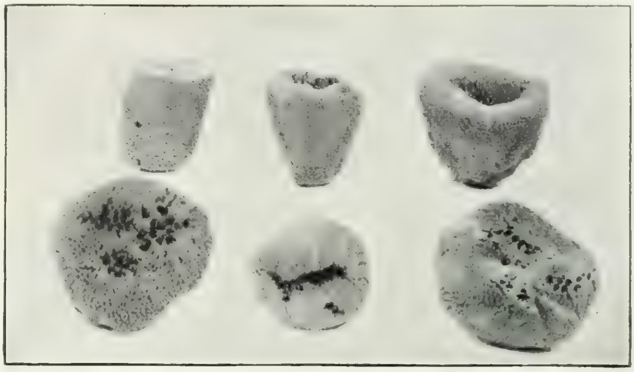


FIG. 14.—"CUPS" AND "SOLID" SPONGES.
All these are varieties of fine Turkey sponges, which receive the distinctive names of "Mandruca," "Benghazi," and "Greek."

FIG. 15.—THREE GRADES OF BROWN TURKEY SPONGES.

C.—BATH SPONGES (HONEYCOMBS).

These are so named on account of their large, perforated, but unequally orificed, honeycomb appearance. They are large and dome-shaped, and their fibre is stout and resilient, while they readily take in and part with water.

Sponges from Florida, Cuba, and the Bahamas are classed as follows :—

1.—REEF SPONGE—a sort with fine, soft fibre, and generally of good form.

2.—GLOVE SPONGE, which has soft, fine tissue, but which is not strong.

3.—FLORIDA CUP GRASS SPONGE. This corresponds from the natural history point of view to the fine Turkey (*Spongia officinalis*). Some "grasses" from the West Indies may belong to this species; others may be referred to *Hippospongia equina.*

4.—HARDHEAD, which has a coarse, hard fibre.

5.—YELLOW. These sponges have been put down as non-Mediterranean forms of brown Turkey (*S. Zimocca*).

6.—SHEEP'S WOOL, with white or yellow fibre.

7.—VELVET, with brown fibre.

As regards the finer sorts of Turkey sponges, they are comparatively, though not entirely, free from sand or gritty particles ; whereas with the inferior kinds it is too often the reverse. Another curious circumstance worthy of notice is that when the north winds blow in the Mediterranean the sun-dried sponges then suck up so much moisture as to increase their weight by almost one-tenth part. The wily Greek traders then try to effect their sales, but the wary purchasers prefer to wait, while only the inexperienced dealer then buys.

From these facts it is evident that the merchant distinguishes a scale of qualities, absolutely based on differences and distinctions of structure. In his own way he thus classifies and appends a name whereby others may recognise, to a certain extent, the peculiarities of the object

intended. Now this is precisely what the naturalist does in specifically and generically naming and arranging the various forms of living plants and animals.

Besides the sponges of commerce, there are vast numbers of other types — only met with, however, in museums, or occasionally as ornaments. Of these, it is not intended here to say more than that some contain much lime, others flinty material, and those like our common sponge, a horny substance. These distinctive skeleton characters, therefore, yield as many divisional Orders—viz., CALCAREA, SILICEA, and KERATOSA ; though naturalists are by no means unanimous in adopting this grouping of the lowly organised but nevertheless interesting class, PORIFERA.

AIR AND GAS.

WHAT does common observation teach us of the properties of air ? Very little indeed. In our study of the machinery of the air we have not many common phenomena to guide us, as we have in the case of ice, water, and steam. Everyone knows that ice melts when heated, and that hot water gives off steam ; but in our present inquiry we have very little to start with.

We all know that when air is in rapid motion it exercises pressure.

Anyone who has ever "popped" a paper bag knows that air, although it can be compressed, resists compression, and, in fact, presses out against the compressing force. We all know that air expands when heated—at least, everyone who has noticed that hot air ascends will see by a little thinking that this means that a given weight of air occupies a greater space when hot than when cold.

In this paper we are going to explain some of these properties of air, and some other properties analogous to them, which will help to make their causes clear ; to describe the effect of changes of pressure and temperature upon air and gases ; and, finally, to state the mechanical theory which there is strong grounds for believing competent to explain all the preceding phenomena.

For the present we will confine ourselves to atmospheric air, as it is the gas which is most convenient to experiment on, and, as we shall see, the properties which it possesses are common to all gases.

That air has weight may be shown by a very simple experiment (Fig. 1). From a large flask closed by a tap the air is pumped out by means of an air-pump (Fig. 2). The tap being closed, the flask is placed in one pan of a delicate chemical balance, and counterpoised exactly by weights in the other pan. If the tap now be turned, and the air admitted to the flask, it will be found that the pan containing the flask sinks, and that more weights have to be added in the other pan to counterpoise it. These added weights are equal to the weight of the air which had been previously pumped out of the flask.

The weight of 100 cubic inches of dry air at a temperature of 62° Fahr., and when the barometer stands at 30 inches, is about 31 grains. The same volume of hydrogen gas under similar circumstances would weigh 2·14 grains. The weight of a cubic foot of air is approximately 1·293 oz.

It may be added that water is 773 times heavier than air at the ordinary pressure of 30 inches, while both are at 32° Fahr.

We know that air can be compressed,

and that it resists compression. An air-cushion is compressed a little when a light man sits on it, and a great deal when a heavy man does the same. We also know

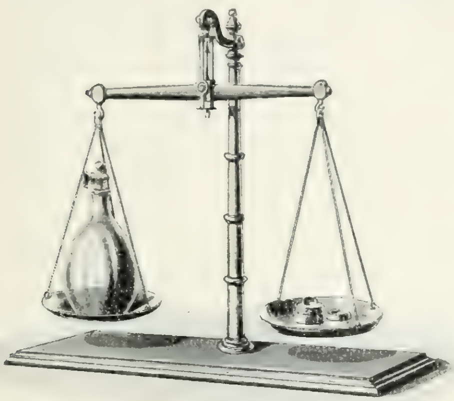


FIG. 1.—PROVING THAT AIR HAS WEIGHT.
A cubic foot of air weighs about 1·293 oz.

that the pressure of air increases as it is heated. If we blow a bladder full of air, and, having tied up the neck, place it in front of the fire, the pressure inside will increase, the bladder will swell, and when it can stretch no further it will burst. A fully inflated bicycle tyre will, if the machine be stood in a hot room, or in the full glare of the summer sun, be in danger of bursting, as most experienced cyclists are aware.

Before we go on to examine the laws illustrated by the above phenomena, we must try and realise what is the essential difference between a liquid and a gas.

If we put a small quantity of liquid into a large bottle, the liquid will not fill the bottle ; it will fill the lower part of the bottle, and there will be a level line at the top of the water. If, on the contrary, we take the largest possible bottle, and introduce into it the smallest possible quantity of air, or other gas, that gas will entirely fill the bottle ; there will be no line of separation, and we shall not be able to say that there is more gas in one portion of the bottle than there is in another.

A gas may, then, be defined to be, matter in that state in which the smallest portion of it will entirely fill the very largest possible containing-vessel. In other words, gases have a tendency to indefinite expansion, which expansion is only limited by the sizes of the vessels in which they are contained.

If we have an air-pump, with several "pressure-gauges" attached to different parts of it, and if, after pumping out the air, we readmit a small portion through any opening, all the gauges will rise equally ; showing that the air has distributed itself uniformly in every part of the receiver.

We have said that if we increase the pressure of air, we diminish the volume. The question arises at once, How much diminution of volume will be produced by a given increase of pressure ? or in other words, what relation exists between *volume* and *pressure ?*

The question has been answered experimentally by Boyle* and Marriotte, who

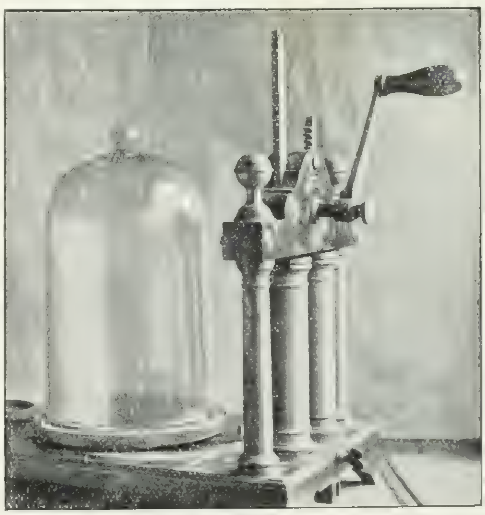


FIG. 2.—AN AIR PUMP.

worked independently and obtained the same result.

"Boyle's law" states that "the pressure

* The Hon. Robert Boyle (1627–1691), the discoverer of Boyle's law, mentioned above, is said to have made the discovery seven years before Marriotte (*see* "Introduction").

of a given quantity of gas, whose temperature remains unaltered, varies inversely as to its volume." Thus, if we have two glass vessels, the one containing twice as much as the other, and a cubic foot of air be placed in each, the pressure in the smaller one will be twice as great as the pressure in the larger one, and *vice versâ*. Stated generally, this means that if the volume be multiplied by N, the pressure will be divided by N.

Experiments made by Regnault and Despretz go to show that Boyle's law is not quite accurate for all gases, although when dealing with air, oxygen, hydrogen, and nitrogen, or, generally speaking, gases which do not liquefy easily, it is so near to the truth that the difference may be ignored. A gas which obeys the "law" as given by Boyle exactly would be a *perfect gas*. Air is nearly perfect, but most gases are a little more compressible than the enunciation of the law given would lead us to expect.

A necessary "corollary" of the above is, that, if, instead of diminishing the volume, we double the quantity of air in a given vessel, we double the pressure.

Professor Rankine has stated this law in another form, which places it in a very clear light. He says:—"Let us take a closed and exhausted vessel, and introduce into it one grain of air. This, we know, will exert a certain pressure on every portion of the sides of the vessel. If now we introduce a second grain of air, this second grain will exert on all sides of the vessel exactly the same pressure as it would have done if the first grain had not been there before it. So the pressure will now be doubled, because the two grains together exercise double the pressure that either would have exercised separately."

Thus each portion of gas in a closed vessel exerts the same pressure against the sides of the vessel as if the other portions had not been there.

The total pressure is the sum of the pressures exercised by all the different portions, or, in other words, is proportional to the quantity of gas in the vessel; that is, that if, for instance, we have 3 oz. of gas exercising when alone a pressure, we will say, of 30 lb. to the square inch, and we add 2 oz.—which, if alone in the same vessel, would have exercised a pressure of 20 lb. to the square inch—the total pressure due to them both together is 50 lb. to the square inch; that is, it is the *sum* of the pressures due to each portion.

The quantity of gas in a vessel of unit volume is called the "density" of the gas.

This may also be expressed by saying that the density of the gas in any vessel is equal to the quantity of gas divided by the volume which the vessel will contain.

We may now say that the density of a gas varies directly as the pressure, and the pressure exerted by any given gas varies directly as its density.

A little consideration shows the proposition about the increase of pressure exerted by the gas when the volume is reduced to be a necessary consequence of that about the diminution of volume when the pressure is increased, for when equilibrium is established, the outward pressure of the gas must be equal to the inward pressure exercised by the external forces upon it.

The same law holds for mixtures of different gases as well as for simple gases, for, if a grain of one gas be put into a closed, exhausted vessel, and then a grain of another, each will independently exercise its own pressure, in the same way as if they were two portions of the same gas.

What is called "Charles's law" is this: Gases expand when heated. Charles discovered that at any pressure whatever, so long as the pressure is constant, the expansion produced by a given increase of temperature is constant, and the same for all gases. If at any pressure the volume of any gas whatever at 32° is unity, then, if the pressure remains constant, the volume at 212° will be 1·3665.

That is, 30 cubic inches of air at 32° F. will expand to about 41 cubic inches at

212° F ; and this law--namely, that the expansion caused by a given rise of temperature is constant—has been found to be true, not only for the range of

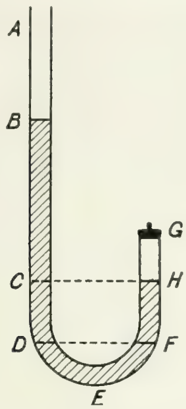


FIG. 3.—THE RELATION OF PRESSURE TO VOLUME.

temperature between 32° F. and 212° F., but for every other temperature at which it has been hitherto tested.

Another way of stating this law is that, when not allowed to expand, the pressure of a gas increases by an equal amount with each degree by which its temperature is raised.*

We have hitherto only stated a number of empirical laws about gases. Now let us proceed to the theory, which shows that all these, and many other, phenomena, are necessary results of one simple natural fact, and, further, we shall be able to deduce from the theory facts about the internal constitution of gases which must for ever remain insensible to direct experiment. For if it is found, as in this case, that a theory explains every phenomenon out of a vast number observed, and contradicts none, we are justified in considering things to be proved which are necessary consequences of the theory, even when, as has been already stated, they can never be put to the test of direct experiment.

If we double the pressure, we halve the volume ; if we treble it, the volume is one-third ; if we quadruple it, one-fourth, and so on.

The working of Boyle's law, which, by the way, is spoken of by Continental scientists as Marriotte's law, may be demonstrated as shown in Fig. 3. Take a bent glass tube, A E G, of uniform bore, the arms, E A and E G, being straight, and E A much longer than E G ; G is an air-tight cap. Remove this cap and pour into the mouth of the longer tube, at A, a little mercury—enough to fill the bend to the level D F. Replace the cap, and note that the volume of the air in the short arm is represented by F G. Now pour in more mercury at A until it stands at B in the longer arm of the tube. But it has not risen to an equal height in the short arm, but only to the point marked H, and the air formerly contained in that part of the tube between F and G is now compressed in H G. The volume has been diminished, and the pressure resulting supports the weight of the column of mercury, C B.

We have now demonstrated two things : (1) that under certain circumstances the *volume* of air may be diminished ; and (2) that accompanying this diminution of volume *pressure* is established. There is a fixed relation between this *volume* and the resulting *pressure*.

Those readers who have not had a mathematical training would find it difficult to follow the process of reasoning by which this "relation" is calculated ; it may therefore be stated at once that :—

$$\frac{\text{2nd pressure}}{\text{1st pressure}} = \frac{\text{1st volume}}{\text{2nd volume.}}$$

The workings of the same law for an expansion of air may be demonstrated by the experiments illustrated in Fig. 4. A vessel, D, is filled with mercury. A quantity of the same convenient substance, but not enough to fill it, is poured into the tube *a b*, this tube having one open end, at *b*. This tube is held in the vessel in the manner shown in the figure, so that

* A rise of each degree Centigrade ($\frac{5}{9}$ Cent. = 1° Fahr.), increases the volume by a quantity equal to ·003665 of the volume at 0° Cent.

the tube contains air at *a c* at ordinary atmospheric pressure, and the surface of the mercury in both tube and basin is represented by *c*, the point to which the tube is at first sunk.

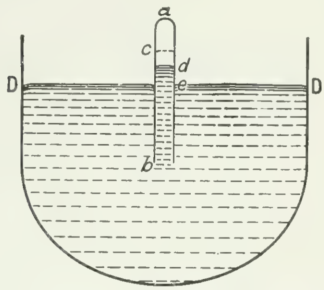


FIG. 4.—ANOTHER ILLUSTRATION OF THE WORKING OF "BOYLE'S LAW."

The tube is now raised a little, to *e*, the volume of air at *a c* expands, and the surface of the mercury in the tube falls to the level *d*, the air occupying the space *a d*, instead of *a c*, as at first. It will be noticed that the mercury in the tube is now at a higher level than the mercury in the vessel.

Prefacing then that the separate very small portions of which gases and other forms of matter are composed are called *molecules*, we may briefly state the "kinetic theory" of gases as follows :—The molecules of all gases are in a state of rapid motion. They constantly strike each other and the sides of the vessel. The blows on the sides of the vessel form a continuous bombardment, and the bombardment *is* the pressure which the gas exercises on the sides of the vessel.

Now, as an illustration of the fact that a bombardment may produce a continuous pressure, let us take one of the machines seen at fairs for determining how hard one can hit. It consists of a cushion pressed forward by a spring. The blow compresses the spring for an instant, by an amount depending on the hardness of the blow. In the case of a single blow the compression is only instantaneous.

If, however, we had an immense number of men all hitting at a very big machine, but not at the same time, the spring would be permanently compressed —*i.e.* the effect of the continuous shower of blows would be to produce a steady pressure on the cushion. The amount of this pressure would be equal to the *average* strength of each blow multiplied by the *average* number which fell at once. When we are dealing with immense numbers, the law of averages approaches more and more nearly to absolute exactitude. The error which we make in saying that the pressure of a gas whose temperature and volume do not alter is absolutely constant is far smaller than the finest instruments ever likely to be invented could detect.

The actual pressure of a gas at any instant is seldom mathematically equal to the mean pressure, but the oscillations on each side of the mean pressure are of so exceedingly small an amount, and last each such an exceedingly small fraction of a second, that no experimental method can ever be expected to show the least difference.

The molecules, in their path from one side of the vessel to the other, are constantly striking other molecules, and by rebounding have the directions of their motions changed. Now, it is by no means necessary that any molecule should strike another in its path across the vessel, for the average free space between two molecules is many times the average thickness of a molecule. We can only say that, owing to the enormous number of molecules, and their great velocity, such a thing as a molecule getting across a vessel without striking another is very unlikely. It is much more unlikely that a large number—say half the molecules—should cross the vessel in the same direction without striking any other molecules.

It is, however, perfectly possible physically. Let us consider for a moment what would be the effect of half the molecules of air in a glass bottle simultaneously travelling to one side of the bottle, and the

other half to the other, without any collision on the way. The total blows struck on the sides would be so powerful that the bottle would be instantly blown to atoms.

It may be claimed that such an event as a bottle of cold air exploding has never occurred, but the reason why it has not is only that the chances against the necessary arrangement of the molecules taking place are so great that they are practically infinite. There is no physical reason against the possibility of such an occurrence.

This theory at once explains Boyle's law ; for the pressure of a gas is proportional to the strength of the average blow of each molecule multiplied by the number of blows falling in a second. If we double the number of molecules by doubling the quantity of gas, we do not affect the hardness of the blows, but we double the number per second, and hence double the above product—that is, we double the pressure.

Now, this is the law which Boyle and Marriotte discovered experimentally. Again, with the law of Charles, it can be shown by the theory that the temperature of a gas depends in a particular way on the average velocities with which the molecules are moving. Also the theory shows that the average blow depends, in the same way, on the velocities with which the molecules are moving.*

Hence, the theory shows that the average blow varies directly with the temperature.

Now, if without altering the number of molecules—that is, without altering the quantity of gas in the vessel—we increase its temperature, we shall, according to the theory, cause an increase of pressure proportional to the increase of temperature, for the pressure is equal to the average blow multiplied by the number of blows. Doubling the average blow then doubles the pressure.

But this is one form of the law of Charles previously discovered experimentally.

The theory has stood the test of experiment in many other cases which are too complicated to be explained here, and it may be considered to be completely established.

Mathematicians have therefore been justified in going on to deduce from the theory propositions about the motion of the molecules which cannot be tested directly by experiment.

The only one which we shall give here is the deduction of the mean velocity with which the particles of oxygen gas at rest under the ordinary atmospheric pressure, and at a temperature of 32° Fahr., are moving.

It is found that the average velocity is about 6,097 feet, or nearly $1\frac{1}{4}$ miles, per second.*

Thus we see an example of the formation and application of a scientific theory. The theory is first tested by its accordance with known facts. Then it is applied to measure with absolute accuracy the velocities of molecules so small that millions of millions are contained in a cubic inch, and all moving some sixty or seventy times as fast as the swiftest railway train.

* Both depend on the square of the velocity (*see* Maxwell, on "Theory of Heat," ch. xxii).

* This quantity, which is nearly the average velocity, is the exact square root of the mean of the squares of the velocities.

MILK.

By C. W. WALKER-TISDALE.

(Lecturer in Dairy Farming and Dairy Bacteriology at University College, Reading.)

IN appearance milk is an opaque liquid with a slightly yellow tinge, due to the presence of the fat. If the fat be removed, or skimmed off in the form of cream, an opaque liquid of a bluish-white colour is still left behind. Without the agency of chemical apparatus it is possible to demonstrate the composition of milk by ordinary dairy operations. For instance, starting with new whole milk, if it is allowed to stand in any vessel the cream rises to the surface and we get two portions—the cream, which has as its most important constituent butter fat, and also skim milk. If a separator be adopted for the purpose of splitting up the milk, we get cream and separated milk. Now it is of considerable importance to the public at large to distinguish the difference between skim and separated milk, as the food value of the former is much greater than that of the latter. Skim milk contains an appreciable amount of butter fat, namely, about ·75 per cent. owing to the incomplete separation of the cream by simply allowing the force of gravity to act. In the case of separated milk the fat contents will not amount to more than ·1 to ·15 per cent., although the other constituents will be much the same. Centrifugal force, as adopted in the case of the separator, is so very thorough that it only leaves a mere trace of fat behind. Under the Sale of Foods and Drugs Act, 1899, however, both skim and separated milk come under the same heading, and must contain not less than 9 per cent. of solids.

Taking the skim or separated milk, if we add either a little rennet or acid to it, and keep it slightly warm, a further separation is obtained, and two portions result, viz. (1) a solid which is the *curd* and consists chiefly of a body called *casein*, and (2) a liquid of a greenish yellow tinge, the *whey*, which, in reality, is a solution of milk sugar containing a little albumen. This "whey" is a valuable by-product in a cheesemaking dairy, and is turned to good account for feeding pigs and the production of dairy pork.

Whey has also a high dietetic value for invalids. The splitting-up process and the various substances obtained are set out in table form for convenience :—

WHOLE MILK.

CREAM. Composed mainly of Fat.

SKIM MILK + Rennet or Acid.

CURD. Consists chiefly of Casein.

WHEY. A solution of milk sugar, with a small trace of Albumen.

Taking the actual constituents (*see also* Fig. 1) and the proportions in which they exist in milk on an average, the writer has found, per cent. :

Water	87·55		
Butter Fat...	3·70		Total Solids, 12·45 %
Casein and Albumen...	3·10	Solids non-fat 8·75 %	
Lactose or Milk Sugar	4·90		
Ash or Mineral matter	·75		
	100·00		

Two terms which are frequently met with, especially in connection with prosecutions for adulterated milk, are those of *total solids* and *solids non-fat*. The "total solids" represent all the constituents of the milk other than the water, or those which would remain behind if milk were heated and the water driven off. To

obtain the total percentage of these from the above table add together all figures except the water.

The "non-fatty solids" in the above instance represent 8·75 per cent. of the whole.

Until recently there was no standard of quality for milk, and little protection against adulteration; now, however, it is necessary that milk should contain not less than 3 per cent. of fat and 8·5 per cent. of solids non-fat, which is the legal Government standard.

That milk may occasionally fall below this standard is admitted, but it is very rarely the case with well-fed and well-managed herds. One result of careful selection, keeping and breeding from the best animals only, is that the quality will seldom fall even as low as the standard.

A brief enumeration of the constituents and their properties is essential. Commencing, in order, with water, we find this practically in all foods to a greater or less extent. In milk it largely predominates, but it is not present in such a high proportion as in turnips, which contain 92 per cent., or in swedes and cabbages, which contain 88 to 89 per cent. water. Thus milk has more solid matter and less water than an ordinary turnip, though, if judged by appearances, this would not be thought so. Water, either obtained in the food or as pure water, is essential for the solution and absorption of the different constituents when taken into the animal body. Foods that are deficient in water (take, as an example, decorticated cotton cake, which is largely used for feeding milch cows and only contains about 10 per cent. water) need to be supplemented by allowing animals free access to water, when they will drink according to requirements. It is always well for milk production to be able to feed cows on plenty of succulent foodstuffs, and also see that a pure water supply is available. Remember, milk is more than three-quarters composed of water, and this has to be filtered through the cow.

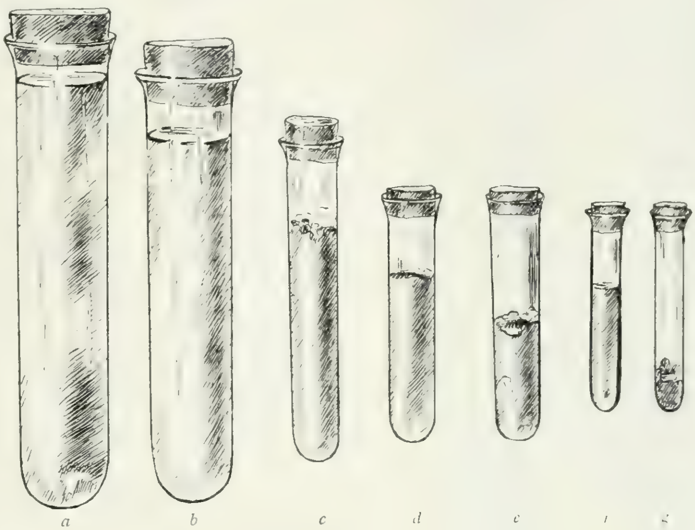


FIG. 1.—A HALF-PINT OF MILK ANALYSED.

a. A half-pint of milk—weight 10 oz. 131 gr.
b. Water—9 oz. 9 gr.
c. Total solids—1 oz. 122 gr.
d. Casein and albumen—weight 140 gr.
e. Sugar—219 gr. f. Fat—166 gr.
g. Ash—34 gr.

A cow in full milk drinks some twelve or sixteen gallons of water a day, it usually being considered by practical dairymen that "a good milker is a good drinker."

The "butter fat" of milk is, commercially, the most valuable of all the constituents, as it is this portion which is used for the production of butter. Now "butter fat" is a very characteristic substance of complex composition, and only found in milk, its fine flavour and digestibility making it the best of fats for feeding purposes. It belongs to that class of substances known as heat givers and energy producers, and is built up of the elements carbon, hydrogen, and

oxygen, the hydrogen being present in greater proportion than is necessary to form water. When a fat is burnt or oxidised in the animal body it generates heat to a much greater extent than a carbohydrate, to which reference will be

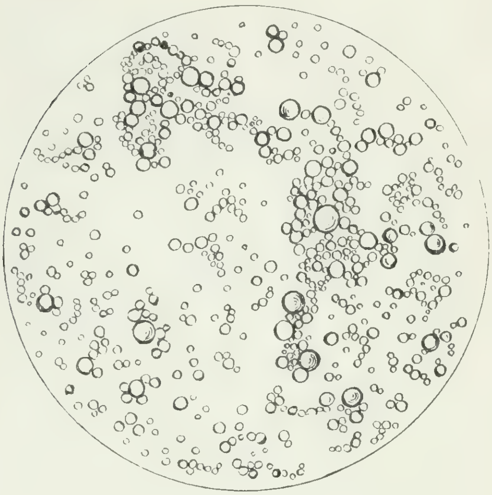


FIG. 2.—FAT GLOBULES IN MILK.
(From a drawing made from a micro-photograph. Magnified 500 diameters.)

made later. In fact, 1 lb. of fat will, when combusted, produce two and a half times as much heat as 1 lb. of a carbohydrate, such as sugar. In the Italian army this has been very practically demonstrated, and it was found that by giving fatty foods to the soldier for breakfast instead of macaroni (starch, a carbohydrate), the men were able to continue twice as long at work.

Fat in milk exists as an emulsion, and a drop of milk examined under the microscope shows innumerable small globules, of which there are several millions present in a pint of ordinary quality (*see* Fig. 2).

The milk first drawn from the udder contains very few fat globules, whereas that last drawn, or the "strippings," is extremely rich and highly charged with fat —indeed, so much so, that it is sometimes unlawfully set aside by the dairyman for butter-making, and not mixed with the rest of the milk. "Strippings" are, in reality, thin cream. The fat is the most variable of all the constituents, and may range from 3 up to 6 per cent. Milk from Jersey and Guernsey cattle is the richest, has the largest fat globules of any, is of a high colour, and yields the best quality butter.

It is essential to understand clearly that, in speaking of butter fat, pure fat, and not butter, is meant. Butter consists mainly of pure fat, about 84 per cent.; but the rest—16 per cent.—consists of water, salt, and traces of the other milk constituents. The relationship of the two is this: 100 lbs. of pure butter fat, when manufactured into butter, owing to the presence of the water, etc., will yield 116 lbs. of butter, or 1 lb. of butter fat makes $1\frac{1}{6}$ lb. of butter.

Cream might be described as a concentrated milk, as far as the fat is concerned. It will contain from 20 to 50 per cent. of fat, according to richness, and its butter-making power depends on the richness. On an average, about a quart of cream will make a pound of butter, and this represents the product of $2\frac{1}{2}$ to 3 gallons of milk.

Under the microscope, cream appears to be much like milk, except that the fat globules look very much larger and are more thickly packed together. Separated milk, examined in the same way, shows only a few occasional globules.

The next constituent, *casein* (together with the albumen) represents the albuminous or flesh-forming portion of the milk, and goes to build up the muscle and tissue of the animal. Split up into its elements, "casein" consists of carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus, and it is to the presence of about 16 per cent. of nitrogen that it owes its name as an *albumenoid*. "Albumenoids" are of different kinds, being derived from both animals and vegetables. Of the former the chief example is found in our daily bill of fare as lean meat,

whilst peas and beans supply familiar examples of vegetable albumenoids. As albumenoids are absolutely essential to life, vegetarians find milk, eggs (the white of egg is pure albumen), peas, and beans particularly valuable.

Casein is only found in milk, but is very similar to the albumenoid *legumin* in beans. It may be recognised from the facts that—

(1) It is coagulated or turned into a clot if either acid or rennet be added to the milk.

(2) It does not clot on heating.

Albumen, on the other hand, is not affected by either acid or rennet, and when the cheese-maker coagulates his milk with rennet the albumen escapes entanglement, and is lost in the whey. Very different, however, is its action on being heated. The white of an egg is

FIG. 3.—THE ORGANISMS THAT TURN MILK SOUR.
Bacillus Acidi Lactici. Magnified 1,200 diameters.

soluble in cold water, but immediately a raw egg is dropped into boiling water the albumen coagulates. The albumen in milk is similar; it clots if heated to a temperature of 170° Fahr., and may be seen to form a skim on milk that is boiled. It can also be obtained as a gluey mass from heated whey. Albumen lacks one element that casein possesses, and that is phosphorus.

Milk, if kept, sours and clots, and the explanation of this clotting is that it is due to acidity. Casein is bound up

FIG. 4.—CULTURE OF BACTERIA IN GELATINE
This is a pure culture of Bacillus Acidi Lactici.

intimately with lime, and as soon as the milk becomes acid the lime is neutralised by the acid and the casein set free from its combination.

Milk sugar is characteristic of milk, and is not found elsewhere. It is a carbohydrate —that is, a body built up of carbon, hydrogen, and oxygen, the latter two elements being present in the proportion to form water. Milk sugar is easily obtained by evaporating off the water from whey, and a large trade is done in this article.

It is harder than cane sugar, not nearly so soluble in water, and possesses very little sweetness. Milk sours, cream ripens, and curd ripens or matures owing to the turning of milk sugar into lactic acid by lactic acid bacteria.

Lactic acid bacteria (*see* Fig. 3), of which a great number of species are known, are very useful micro-organisms in many respects, assisting, as they do, in the manufacture of dairy produce. Indeed, they are so valuable that in most up-to-date dairies they are specially grown, the cream being inoculated with them to ripen it.

The culture shown is a pure cultivation of *Bacillus Acidi Lactici* (Fig. 4). This bacillus grows by simple cell division, and the numbers of the cells become innumerable in a few hours if the temperature is suitable to their growth. If cooled down to a very low temperature, bacteria cease growing, but they are not killed, and when warmed up again are as vigorous as ever. On the other hand, heating to about 140° Fahr., and above, is sufficient to destroy even some of the most virulent germs, such as those producing such infectious diseases as typhoid fever, diphtheria, and consumption.

The lactic acid bacteria live on the constituents of the milk, which is a perfect food for them, at the same time turning the milk sugar into lactic acid. This action goes on until the milk becomes so sour and clotted that the medium becomes poisonous to the bacteria, which then cease growing.

Milk sugar is, like fat, a source of heat when burned in the animal body. Carbohydrates and fats must be combusted to keep the animal warm, as the temperature of a human being in health is $98\frac{1}{2}$° Fahr., of a cow $101\frac{1}{2}$° Fahr., and the warm body is always subject to evaporation of heat into the outer air.

Last of the constituents comes the ash or mineral matter, which is the portion of the milk that cannot be dispelled by heating. To find the proportion of ash in milk a certain portion is weighed out and evaporated, the total solids thus obtained being exposed to further heating in a furnace, when the casein, fat, and sugar will be driven off, leaving only "ash" behind. The chief value of mineral matter is that it supplies the substance for building up both bone and brain of an animal, the main constituents being lime, potash, and phosphoric acid, the phosphate of lime providing the hard parts for the bony structures.

A great deal has been written as to the advantages of pasteurised and sterilised milk, but for my part I prefer pure new milk, produced under modern sanitary conditions, rather than that to which any after-treatment in the form of heating has been given. Heating slightly alters the nature of the milk, and, although it kills the bacteria, renders the lime salts to some extent insoluble. Deficiency of lime salts in the food is the prime cause of rickets in children, and unless these salts are supplied by the milk they require to be given to young children in the form of lime water or other suitable ways.

Undoubtedly pasteurisation and sterilisation of milk for public consumption have many advantages, and sterile milk is valuable for infants in hot weather in preventing the ailment known as summer diarrhœa, caused by the excessive quantities of bacteria which are present in raw milk.

The majority of people, unfortunately, do not actually realise what a valuable food milk is, though the fact is slowly penetrating to the public mind, as evidenced by the very large and growing yearly demand for this article. Thousands more cows are now required each year to keep up the supply, and even milk from other countries—chiefly France—is being imported. The poor look upon milk more or less as a luxury rather than an excellent food, owing to its price, which is considered beyond reach, and few can be made to realise that in reality it is a much cheaper article of diet than meat and many other foods and beverages considered as necessary. For instance,

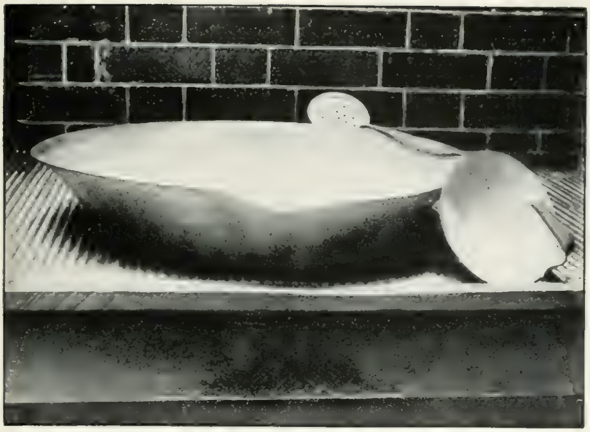


FIG. 5.—SEPARATING THE CREAM FROM THE MILK.
The old method of "setting" and "skimming."

compare it with meat, and we find that a quart of new milk contains about the same amount of nutritive material as a pound of beef-steak. The difference in price, however, is tremendous—3d. or 4d. will purchase a quart of milk from the retailer, whereas 10d., or 1s., or even more, is the price per pound of steak.

Again, compare milk with beer. This latter beverage only contains about 5 per cent. of nutritive matter, which consists chiefly of sugar, or less than half of what milk shows, the constituents of milk being, moreover, very much more valuable, as making up a perfect food, whereas those of beer do not. Certainly, beer is a stimulant, containing, as it does, some 4 or 5 per cent. of alcohol: this makes it pleasant to some as a beverage, but it is very expensive as a food.

Milk as the sole diet for adults would not do, owing to the quantity it would be necessary to consume: one and a half gallons per day would be required to supply the necessary nutriment. On the other hand, it should be made to enter largely into the diet of every person, infants, of course, living entirely upon it for some time after birth.

It may be interesting to those unacquainted with the chemistry of digestion to describe how milk is dealt with in the stomach. A young animal drinks the milk naturally in small streams, which, when entering the stomach, meet with the gastric juice and are clotted or coagulated by the unorganised ferment, rennet, contained in it. These small clots are gradually broken down and dissolved also by the rennet, assisted by the juice, which also contains *pepsin*, another unorganised ferment. From this it will be seen that it is essential that milk be taken in small quantities at a time, and not gulped down, as large clots in the stomach are with difficulty broken down by the juices. This is very clearly demonstrated by the fact that very often young calves, when fed from a pail instead of being allowed to suck the milk from the dam, suffer from a digestive trouble which produces diarrhœa and is known to farmers under the name of "white scour." When taking milk from a pail they gulp it down very rapidly, and so large clots of milk are formed in the stomach which do not get broken down and assimilated, but set up irritation, causing the trouble. Milk is practically all digestible, so that none of the constituents are lost when milk is used as a food. It may be made lighter and still more suited to invalids suffering from

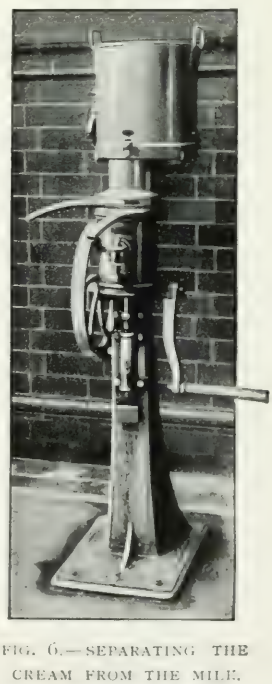


FIG. 6.—SEPARATING THE CREAM FROM THE MILK.
The modern method—by means of a "separator."

serious stomach troubles by submitting it to certain fermentative changes, thus producing peptonised milk.

So far I have shown how cow's milk is built up, and a very few words will suffice for the milk of other animals. Whatever the animal (there are a few vegetable milks), the milk is built up of the same constituents, though the proportions in which they exist vary considerably. The following table after König gives the different compositions :—

AVERAGE COMPOSITION OF DIFFERENT MILKS.

	HUMAN.	MARE.	GOAT.	ASS.	EWE.
Water ...	87·41	90·78	85·71	89·64	80·82
Fat	3·78	1·21	4·78	1·64	6·68
Casein ...	1·03	1·24	3·20	·67	4·97
Albumen	1·26	·07	1·09	1·55	1·55
Lactose .	6·21	5·67	4·46	5·99	4·91
Ash	·31	·35	·76	·51	·89

If we refer back, and compare cow's milk and human milk, it will be seen that the casein and albumen and also the sugar are very different in proportions, and on these points is based the preparation of humanised milk now carried out on a large commercial scale. Cow's milk with a lot of casein very often proves too strong for the delicate digestions of infants and invalids, and so casein is removed and sugar added to make it resemble human milk as nearly as possible. The milk of the ass resembles human milk in its properties, and is valuable as a substitute for it. Several herds of asses are kept in the vicinity of London to supply this commodity to the public. Sheep's milk is very rich in fat, and was at one time largely used in the manufacture of Roquefort cheese.

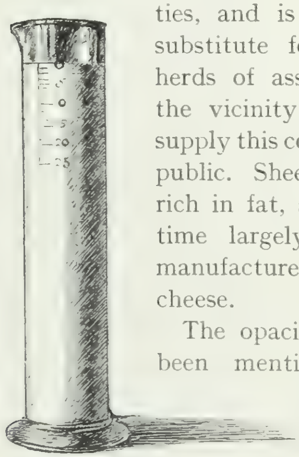


FIG. 7.—A CREAMOMETER GRADUATED FROM 0 TO 25.

The opacity of milk has been mentioned as being due to the fat globules, and some of the first methods brought out for testing milk were based upon the reduction of this opacity. With Feser's lactoscope a measured quantity of milk was gradually diluted with water until it was possible to see through the milk certain black lines marked on porcelain. It only remained to note the mark, showing how much water had been added, and on a line corresponding with this the quantity of fat in the milk was indicated. Now, if the opacity of milk was solely due to fat this would be an accurate test, but this is not so. After removing the cream from milk we have left behind skim milk, which is still more or less opaque, due to the presence of casein, which is mostly in suspension in the milk, only a small quantity being in solution. Of the many methods of testing milk none so far brought out is of any use whatever to the ordinary householder.

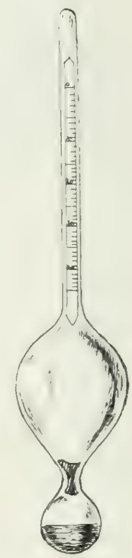


FIG. 8.—A LACTOMETER.

The "creamometer," or cream tube, as it is sometimes called (Fig. 7), simply consists of a tall, narrow glass vessel, made to hold 100 parts of milk and graduated at the top from 0 to 30. The milk is filled in to the top mark, and must be at a temperature of 60° F. It is allowed to stand for twenty-four hours undisturbed, and then the amount of cream, which will have risen to the surface, may be determined. The graduations show up to 30 per cent. of cream, and milk will usually show about 10 per cent. This appears to be a simple and effective test, but unfortunately, though largely used by many dairymen, it is absolutely unreliable and inaccurate. The reasons of its inaccuracy are briefly these : The large globules in milk rise much more quickly and give a larger volume of cream in a given time than

FIG. 9.—A "GERBER" TEST BOTTLE.

smaller ones; hence milk which contains large fat globules is made to show a superiority over any other. But the amount of cream is no guide as to its quality, for usually the larger the volume the poorer the quality. The percentage of cream has no connection with the actual percentage of fat in the milk. Two samples of milk, each containing $3\frac{1}{2}$ per cent. fat, may yield respectively 8 to 14 per cent. cream in a creamometer.

The lactometer is a special form of hydrometer made for the purpose of testing the specific gravity of milk, *i.e.* the relative weight of a given volume of milk as compared with an equal volume of water, both liquids being at 60° F. and under ordinary conditions of atmospheric pressure. This may be determined by weighing, but for simplicity and quickness the lactometer is best suited for the dairy. As shown in Fig. 8, the lactometer consists of a glass stem and bulbs, the lower one being weighted with quicksilver. On the stem is a scale marked from 0° at the top down to 45°; if placed in water, it would sink down to the 0° mark, the specific gravity of water being 1·0, so that this must always be added to whatever the reading may show. The lighter the milk is, *i.e.* the lower its specific gravity, the further the lactometer will sink down, and *vice versâ*. New milk shows a specific gravity varying between 28 and 35 on the lactometer scale, or, in reality, a specific gravity of 1·028 to 1·035, water being 1·000. It is always

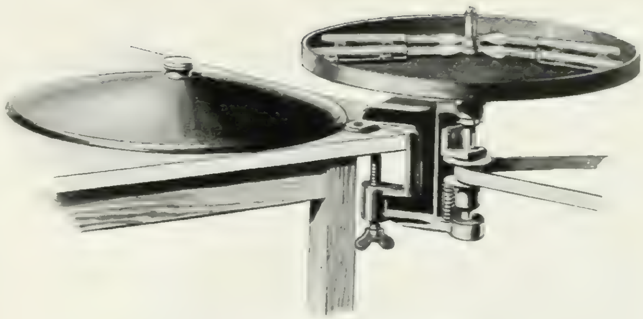


FIG. 10.—GERBER'S BUTYROMETER.

important to test for specific gravity with the milk at 60° F. The fat of milk lowers the specific gravity, whereas the solids non-fat increase it.

The lactometer is not any guide to adulteration, as very rich milk shows a low specific gravity. Water added to milk lowers its specific gravity, so that if skimming is practised and water added the specific gravity remains unaltered within the limits allowed for new milk.

The lactometer is of no use by itself, but is valuable for showing the percentage of total solids in milk when used in conjunction with the Gerber tester.

Dr. Gerber's butyrometer (Fig. 10), the invention of a Swiss scientist, is one of the few quick and accurate methods that can be adopted by farmers and dairymen for estimating the percentage of fat in milk. It is a method almost as good as any analyst's process, and tests may be completed in a few minutes. Test bottles (Fig. 9) are filled in order with 10 cubic centimètres of sulphuric acid, 1 c.c. amyl-alcohol, and 11 c.c. milk. They are then corked and shaken, and the mixture becomes very hot. The bottles are at once transferred to a small rotary machine, and this is kept going for three minutes. All the butter fat is then brought to the surface in a liquid state, and the quantity may be read off on the neck of the bottle, which is specially graduated for the purpose.

THE PHONOGRAPH.

By T. C. HEPWORTH.

THERE is a Chinese tradition extant to the effect that, many thousands of years ago, there dwelt in the Flowery Land a lady with a most entrancing voice. This "Chinese Nightingale" so hypnotised the populace that a general wish was expressed that the sweet sounds of that wonderful voice should not be allowed to become extinct with the death of its owner, and many were the devices suggested for preserving it. At length a wise woman was consulted—a veritable witch, who had the reputation of solving all difficulties, were they never so great—and she produced a bamboo closed at one end, with instructions that the songstress was to sing one of her sweetest melodies into the tube, which was to be then corked up and deposited in a certain temple. Her behests were faithfully carried out. Many generations had passed away, when there happened to be in the neighbourhood of that temple a youth who was told of the dulcet tones shut up in that stem of bamboo, and he determined to feast his ears upon them. To his great delight, the notes welled out in all their original sweetness, and for a few minutes he was enchanted. But the song departed for ever; it was never heard again. This happened, we are told, many thousands of years ago; but the nineteenth century produced an instrument which will not only bottle up sweet music, but will give it out again as often as demanded. Thus has reality outstripped romance, and given us the phonograph.

This Chinese legend expresses in a manner the desire that has been felt, it would seem, among all nations from a remote time, to imitate the sounds of the human voice. Many contrivances have been suggested, or made, having this object in view, and most of them endeavoured to secure the end desired by a slavish imitation of the natural organs of speech. One of these, possibly the best of its class, came under my personal notice many years back; it was

FIG. I.—A VERY SIMPLE PHONOGRAPH.
The "reed" in the organ pipe is vibrated by blowing into the latter.

known as Faber's talking machine. I was consulted as to its suitability as an object for popular exhibition, and went to see and hear it in order to judge of its capabilities. It was a curious-looking machine, with indiarubber lips, a windpipe, and larynx, the whole being governed by the action of keys and pedals which were very skilfully worked by Mrs. Faber. I was told that the machine would faithfully articulate any chosen words, but "metempsychosis" proved too much for it, and the negotiations fell through.

The way in which the joint action of the vocal cords and the lips in producing a simple sound may be imitated is shown

in Fig. 1. An organ pipe of the reed kind is held in the hand, and, while wind is applied with the mouth to throw the contained reed into vibration, the bell of the pipe is closed and uncovered by the hand, when the pipe can be made to call out "Mamma" in most realistically plaintive tones. A doll capable of the same vocal effort, and worked on the same principle, can be seen at the toy-shops.

So long as experimenters endeavoured to create human speech, they failed: success attended their efforts to reproduce it. The first instrument which achieved this wonderful result was Graham Bell's telephone in 1876—an appliance which has since become so common, so necessary a part of everyday life, that it has ceased to excite any surprise. But to the thoughtful man, how marvellous it must ever be that he is able to converse with a fellow-being, although the two are separated by a hundred miles or more, and that communication is so perfect that he can recognise all the peculiarities and mannerisms of his friend's mode of speech!

A characteristic feature of Bell's telephone was the diaphragm, whose vibrations gave out the sounds, and it was when Edison was handling the instrument in question that it occurred to him that such a diaphragm, if it had a point attached to it, might be made to stab a record of its message into a soft substance passed in front of it. And then, if such a record were moved against the point which originated it, it would be possible to throw the diaphragm once more into its original movements, and the sounds which actuated those movements would be reproduced. It was thus that Edison was led to construct his first phonograph—an instrument which perhaps excited more general surprise than the telephone of Graham Bell which preceded it, and of which it was, in a manner, the outcome.

As may be imagined, the production of this machine, doing far more by simple means than had been accomplished by the most elaborate mechanism employed in former so-called talking machines, made a profound impression, and many

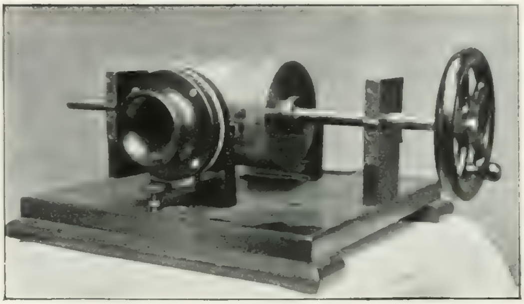


FIG 2.—THE FIRST PHONOGRAPH MADE IN ENGLAND.

were the prognostications of the wonders which it would achieve in the future. It was an American machine, and American descriptive writers have a gift of making the most of things. This was a contrivance after their own heart, and they did not neglect the opportunity for "tall" writing which it afforded. There was little prospect of an early appearance of the Edison phonograph in England, so that we in this country had to take its alleged capabilities for granted.

But soon after its *début* in America a gentleman who had seen and heard it came over here and gave a verbal description of it to Mr. Augustus Stroh, and that clever worker was able to produce within a very few days a machine which would talk. A photograph of this very machine is shown at Fig. 2, and I must here express my indebtedness to its author for his great kindness in allowing me to take this picture, as well as several others which illustrate this article.

This early phonograph has more than ordinary interest attached to it, in that

it was shown at the Royal Institution during a lecture by Sir W. H. Preece, on which occasion the late Poet-Laureate, then known simply as Alfred Tennyson, occupied the chair. After the mechanism of the instrument had been explained, Professor Tyndall, in compliment to the poet, shouted into it "Come into the garden, Maud." Presently the phonograph repeated the words in a comical falsetto, and the effect upon the audience was so startling that they broke into tumultuous applause such as never was heard before within the sedate walls of the famous Institution.

An examination of the illustration (Fig. 2) will enable us to understand the simple nature of the instrument as originally devised. A broad base board has two uprights in which turns a shaft with a screw thread upon it, a corresponding thread being formed on the journal in which it works. At the end of the shaft is a heavy flywheel and a handle by which it can be rotated. Also upon the shaft is a brass cylinder of about five inches in diameter, which has a screw cut in it of the same number of threads to the inch as the screw upon the shaft. In front of the cylinder is a mouthpiece, at the back of which is a diaphragm with a pin in the centre, which just dips into the groove of the screw thread on the cylinder. This cylinder is covered with tinfoil, and if the handle be turned while the diaphragm is stationary, the result is that its point makes an unbroken line in the soft tinfoil. But if, while the cylinder is being revolved, words or musical notes are spoken or sung into the mouthpiece, then the diaphragm is thrown into vibration, and the line drawn on the tinfoil is no longer a continuous one, but is broken up into corrugated markings which form a record of the sounds submitted to the instrument. By shifting the cylinder to its first position, which can easily be done by opening the hinged portions of the uprights and making it once more travel in the same direction, the point attached to the diaphragm retraces its own footprints, and the original sounds are reproduced.

Content with having made a machine which would talk, Mr. Edison seems to have dropped the matter altogether. Owing to a technical difficulty with regard to the patent specification, the phonograph in its earliest form could not be protected in Great Britain, and it is perhaps partly due to this circumstance that others tried to improve it.

Among the experimenters were Messrs. Chichester Bell, Graham Bell, of telephone fame, and C. S. Tainter, and eventually these gentlemen produced an instrument of far greater refinement than the phonograph, which they called the graphophone. One had to shout into the mouthpiece of the phonograph to obtain a good record, and that record when made on the tinfoil was very difficult to handle, so tender was it. A whisper was sufficient to form a record on the far more delicate waxen surface employed in the graphophone, and, instead of a blunt point on the diaphragm, the improved instrument employed a sharp cutter, which ensured a far more finely graded record than was possible with the older contrivance. The record cylinder of this machine was made of paper and covered with a thin layer of wax; it was movable, and, while in action, instead of travelling from side to side, remained in one place, while the diaphragm and its cutter performed the lateral movement.

Once more Edison entered the field, and produced what came to be known as the spectacle machine, in which there were two diaphragms—one for recording, of thin glass, and the other for reproducing, of varnished silk. They looked like a pair of spectacles, for they were mounted together, and either one or the other could be brought against the cylinder as might

be required. In 1889 the "spectacle" machine, which had a solid waxen cylinder such as is used at the present day and was driven electrically, was replaced by one in which a single diaphragm acted as both recorder and reproducer, and the next year the two companies, hitherto in rivalry, amalgamated, and the best points of Edison's machine and the graphophone were combined in one complete instrument.

It must be confessed that when the American phonograph made its first bow before a British audience it was regarded with something akin to disappointment. The public had heard many wonders told of its powers of preserving an exact record of sounds spoken or sung into it. It was said that the voices of public orators and songsters would be embalmed, so to speak, for the benefit of posterity, but when they heard its Punch-and-Judy-like utterances they came to regard it more as a toy than a scientific instrument. And a toy, to all intents and purposes, it became, and a favourite one for exhibiting at bazaars and other social functions. But, as we have seen, when its originator dropped it others took it up, and one improvement after another has resulted in the production of an instrument which resembles its prototype only in the general principles of its construction.

We have already seen how Mr. Stroh constructed a machine in this country from verbal description, and how he exhibited it at the Royal Institution. But he did not stop here. He saw that the instrument was open to great improvement, and his first step was to give its cylinder a more steady motion than is possible by a wheel turned by hand. He therefore fitted it with a clockwork train driven by a weight. In this form he exhibited the phonograph at a meeting of the Society of Telegraph Engineers in 1878; and it is interesting to turn to the published "Proceedings" of the society on the evening in question, for we can thus acquire information about the phonograph as it then was. The report says: "The effect upon the mind on hearing the human voice actually spoken by a machine must be experienced to be appreciated. There is something irresistibly comic in its absurd imitation, but at the same time it is impossible altogether to resist a feeling of wonderment, recalling to one's mind perhaps the feelings of Pygmalion or of the hero of 'Frankenstein.'" But the advantage of the steadiness given to the cylinder by the clockwork was quickly recognised when Mr. Stroh's instrument was put into action. Not only, we are told, was the articulation of the spoken words far more perfect, but songs sung into the instrument by Sir W. H. Preece and others were "reproduced with very respectable correctness." This was at the best but faint praise, and shows that, although a great improvement had been brought about, the machine was still far from perfect. At this time, it must be remembered, tinfoil was still employed to make

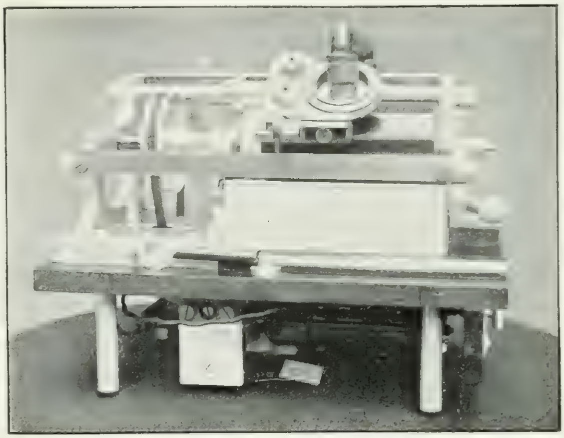


FIG. 3.—A MODERN PHONOGRAPH.
The electric motor which works it is beneath.

the sound indentations upon, and it was considered quite a triumph if a sentence or two, or a few bars of a popular song,

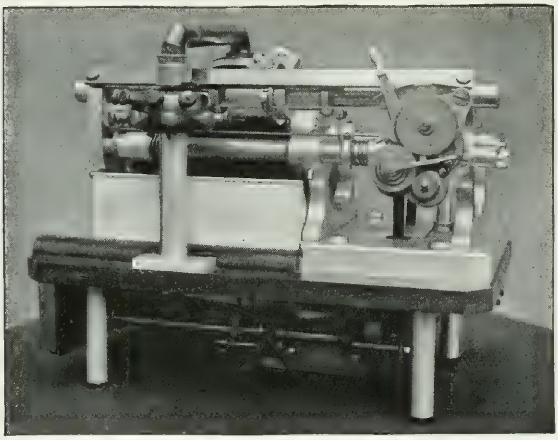


FIG 4.—A MODERN PHONOGRAPH: SECOND VIEW.

Note the waxen cylinder on the right, and the "jointed pipe" on the top, towards the left.

were reproduced in sufficiently accurate fashion to be recognisable.

It was about this time that Mr. Edison constructed a clock with a phonographic attachment instead of a bell to strike the hours. It must have been rather startling for his visitors to hear the clock call out "One o'clock, time for lunch," and similarly appropriate remarks at other hours. The first phonographic cylinder, with a soft tinfoil skin to receive the sound impressions, was cut with about ten screw-threads to the inch, and under such conditions the records could consist of only a few sentences—there was not room on the cylinder for more. A great advance was made in increasing the number of threads to one hundred to the inch, which made the sound record last for about three minutes, or perhaps a little longer. Then two hundred threads to the inch were obtained, and the time of performance was increased to seven minutes. Mr. Stroh succeeded in making a machine of such accuracy that no fewer than three hundred threads to the inch are cut upon its cylinders. The keenest eyesight can detect no more upon the waxen roll than what seems to be a slight dulling of its surface, as if it had been breathed upon. It is necessary to employ a microscope before this dull band resolves itself into an assemblage of exceedingly minute lines, each line being cut up into ridges and furrows by the action of the tiny chisel or cutting point carried by the vibrating diaphragm of the phonograph.

It would be wonderful enough if one of these tiny channels represented the sound record from a single voice or instrument; but when we remember that it is possible for this tiny scratch in the wax to contain the complicated sound records of a full band, which can be reproduced in such a perfect manner that the various instruments can be separately identified without difficulty, we seem to

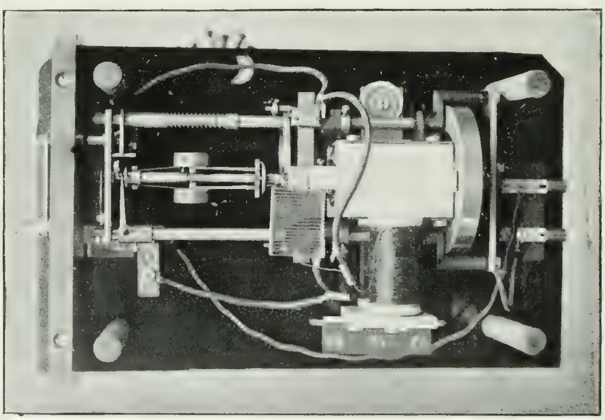


FIG. 5.—ELECTRIC MOTOR USED TO RUN THE PHONOGRAPH.

have arrived at a result which is supernatural. We will now briefly consider the various improvements which have been brought about, chiefly by the ingenuity of

Mr. Stroh, who has taken so much active interest in the phonograph since its first inception by Mr. Edison.

He has made many of these machines, each one becoming obsolete almost as soon as it was completed. Fig. 3 represents one of these beautiful pieces of mechanism, which is chiefly constructed of an aluminium alloy, in order to confer lightness upon it. Beneath it is an electric motor, which needs only to be connected with a battery

On the right-hand side of this figure there is a wonderful little attachment of wheelwork operated by a handle which turns upward. This is to adapt the machine to different records, and make it available for waxen cylinders with 100, 150, 200, or 300 threads to the inch. Other machines lacking this attachment can only be used for records of one number of threads. Fig. 5 shows the electric motor which actuates the phonograph.

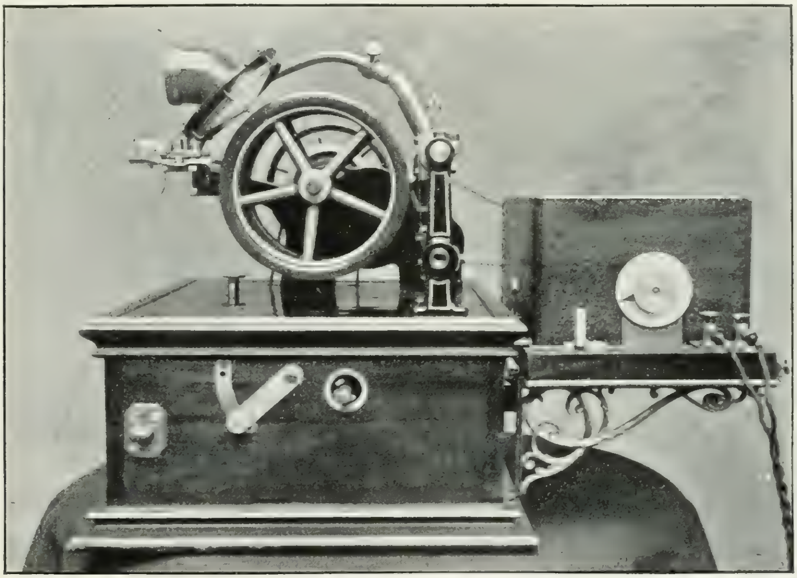


FIG. 6.—MR. STROH'S PHONOGRAPH.

The electric motor is in the box on the right.

cell to give silent movement to the banded wheel seen on the left of the picture. The cylinder upon which the waxen record is slipped, like a sleeve, is plainly seen on the right, and immediately above it is the diaphragm with a jointed pipe above it to carry the sounds emitted to the farther side of the instrument, which is shown in Fig. 4. Here we can follow this jointed pipe, and find that it terminates in a round box with many openings in which pegs are inserted. These openings are for the reception of indiarubber tubes, which lead to the ears of as many auditors as may wish to listen to the machine.

The waxen cylinders employed in this machine are little more than half the diameter of the original tinfoil-covered cylinder in Edison's first phonograph; but now, strange to say, in the newest form of instruments the old size is being adopted once more, and five-inch records, with of course a correspondingly extended surface, are coming into vogue. The extra surface is, however, not used to take longer records, but it is invaluable, seeing that it allows greater space for each sound wave, thereby securing greater detail. One of these records, standing on its containing box, is shown in Fig. 7.

These waxen cylinders are of a very reliable description, and give most marvellous results.

The latest type of phonograph, as employed by Mr. Stroh, is seen at Fig. 6, with its electric motor contained in a box at the right-hand side. Let it be noted that this box has a dial plate with index finger attached, so that the speed of the motor can be altered at will. Most records are marked with the speed at which they should be driven, just as an ordinary piece of music has its metronome number, and it is an important point in either case that the proper speed should be neither decreased nor augmented. The electric has, however, been largely displaced by a spring motor.

We may next observe the big cylinder, with a waxen record upon it; but perhaps the most interesting feature of the instrument is the diaphragm, which is shown more in detail in Fig. 8, for this diaphragm, although at present in but an experimental form, has wrought such a change in the intonation of the instrument that it marks an immense improvement. It has, in a word, eliminated the disagreeable nasal twang which was, until its intro-

FIG. 7.—A WAXEN RECORD.

duction, a characteristic of even the best phonographs. The diaphragm proper is made of thin celluloid such as photographers now often use in lieu of glass, and the conical portion seen in the illustration (Fig. 8) is made of stiff writing-paper, the connecting link between the two being a piece of fine catgut. At the

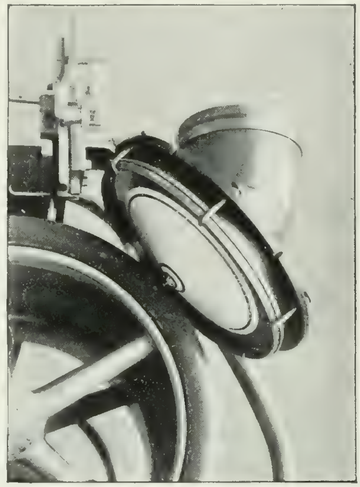


FIG. 8.—THE CONICAL DIAPHRAGM.
This shape of diaphragm is employed to augment and refine the sounds.

apex of the cone is a tiny round sapphire, and this is the point that traverses the little channels cut in the waxen record, and once more causes the diaphragm to vibrate. This cone has the effect of bringing the entire surface of the diaphragm into action, instead of its central portion only, and the effect is not only to refine the sounds, but greatly to augment them. With a long trumpet-mouth fixed to the instrument the sounds are sufficient to fill a large room, and in the case of a tenor with a particularly robust voice who had furnished one of the records, it was difficult to believe that the vocalist was not actually present in the apartment where the instrument was in use. At the same time, the delicacy of the machine is so great that it was easy to hear the singer taking breath between each phrase of the melody.

It may be mentioned as a matter of interest that the idea of the conical diaphragm was borrowed from the Stroh violin, a photograph of which is shown at Fig. 9. In the violin the diaphragm is

made of aluminium, the cone springing from its corrugated edge. Its centre is in connection with the bridge of the instrument, and its vibrations are conveyed to the air within the trumpet-shaped resonator.

As we have seen, the earliest phonograph employed one diaphragm for both recording and receiving; but when tinfoil was abandoned as a record bearer and wax was substituted, it became necessary to use a cutting edge on the point of the recording diaphragm, while a blunt point was employed in translating that record once more into sound waves. The conical diaphragm is not employed for recording, the diaphragm for that duty being made of glass, while the cutting point, attached to a lever, is made of a tiny pencil of sapphire or ruby, cylindrical in form, and hollowed out at the end so that it has a sharp edge. The adjustment of this point is extremely delicate, and much ingenuity has been devoted to its exact form, and the method in which it is mounted, so that it may exert the proper pressure on the wax and accommodate itself to any little irregularity in the surface which it traverses. The waxen cylindrical records are very fragile things, and one may be easily broken by allowing it to fall over on its side. The delicate tracery of the lines formed by the action of the sound waves is also easily injured, the mere touch of a damp finger being sufficient to leave a trace which causes a blurred sound in the phonograph. Recently, however, this brittleness has been obviated by employing a new material for the cylinders, and the improved kind can be flung on the floor without taking any harm. The new material employed for the purpose is, in fact, the same as that of which ping-pong balls are made—namely, celluloid.

To make these celluloid copies of records the original waxen image is placed in the electrotype bath until a metallic skin is formed upon it. The wax is then melted out, and an endless number of celluloid copies can be obtained from the copper matrix. This multiplication of the original waxen records is a most important development, for anyone who has had the privilege of hearing what the perfected phonograph can do will at once see that a big future is in store for it.

FIG. 9.—THE STROH VIOLIN.
The diaphragm here is made of aluminium.

SNOW: WHITE AND RED.

HOAR-FROST may be spoken of as frozen dew; as dewdrops crystallised into ice-needles by the marshalling force of molecular aggregation. It will be by no means difficult to perceive that snow stands in the same relation to rain which hoar-frost holds with regard to dew; it is moisture frozen into ice at the instant that it is condensed out of its transparent and invisible state in the air. But, in the case of the snow, the frozen deposit is formed during suspension in the air, and without any interference from contact with solid radiating surfaces such as is experienced in the production of hoar-frost. The solid particles are consequently grouped into regular geometrical shapes, which are designed by the inherent directive forces of the gathering molecules. Snow forms in the air whenever there is as much aqueous vapour as two and a half grains in each cubic foot, and the temperature is as low as 32° Fahr. Some part of the superfluous moisture, over and above that which can still be sustained in the invisible state, is then set free, and allowed to gather into visible masslets which, as the temperature is below that of freezing water, present themselves as spicules of ice, instead of as tiny drops of water. But when water is slowly converted into ice without any extraneous or interfering strain being brought to bear upon its particles, these are first built up into the shape of a needle, or bar, and six of these bars are then grouped round a common centre, like the spokes of a wheel, with angular intervals of 60° between each contiguous pair of spokes. In Fig. 1 this six-spoked crystal of frozen water is represented in its simplest and most rudimentary form. When snow falls gently in still air, six-rayed spangles, exactly like the one sketched in the figure, are very often seen.

Such simple forms as this primary one are not, however, the only kind that are observed in gently falling snow. If the deposit of the frozen particles is more rapid and more copious, additions of a secondary kind are made to the primary rays. In the first instance, short needles are added to the primary ones, branching out from them at the same angle of 60°, and producing a figure like that shown in Fig. 2. Then the primary rays broaden out by snowy wings, or films, attached along their side, as represented in Figs. 3 and 4, until at last these fuse themselves together into a flat hexagonal plate with six points and six sides (Fig. 5); all these peculiarities are common in falling snow. Sometimes a double system of radiation is planned, with intermediate short rays introduced between the longer primary ones, as in Fig. 6.

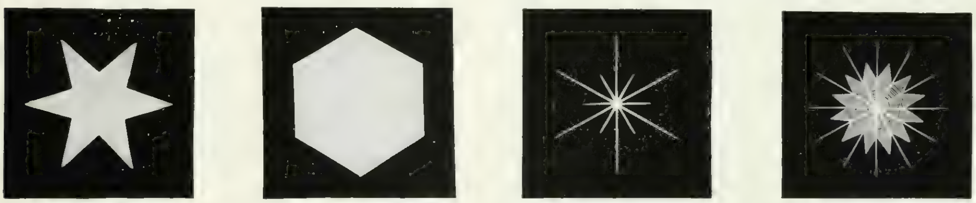
Compound forms are also found based upon this model by the filling in more or less of the interval contained between the rays, as instanced in Figs. 7 and 8. The secondary needles are occasionally further branched with tertiary spikelets, which are then also fixed on at the same typical angle of 60°, as in Fig. 9.

An almost endless diversity of figures, indeed, is constructed, as the rapidity of deposition varies, and as external relations and conditions are changed, but in all the same primary type of six rays and of hexagonal outline, which is the fundamental necessity of the crystallisation of freezing water, is observed. Hundreds of quite distinct forms of snow crystals have been enumerated and described by various observers. Scoresby, an Arctic explorer of some fame, described ninety-six varieties,

in five types. One hundred and fifty-one were noticed during eight days in the months of February and March, in 1855, by the late Mr. Glaisher, and these were all drawn and engraved. The engravings appeared in connection with a


FIGS. 1, 2, 3.—SNOWFLAKES IN THEIR SIMPLEST FORMS.

paper which was attached to the Report of the Council of the British Meteorological Society for that year, and the whole forms one of the most interesting and valuable of the contributions on the subject of snow-crystals which have ever been made


FIGS. 4, 5, 6, 7.—SHOWING THE GROWTH OF THE FLAKES.

to science. Figs. 10, 11, and 12, selected, with others, from this series, will serve to convey some notion of the complexity and beauty of the forms which snow-crystals sometimes present.

The most usual condition in which these snow-crystals are deposited is that of narrow needles, all arranged in one plane, or of thin plates. But the aggregations of the gathering particles are sometimes made in a more solid form, and grow into compact prisms or hexagons. The needles occasionally bristle out all round from a central spherical nucleus. Most complicated and curious figures are sometimes composed by the superposition of two, or occasionally of even more, crystals upon each other. The most complicated traceries are generally produced during the prevalence of extreme degrees of cold. The lightness, regularity, and delicacy of the crystallised spangles is, in general terms, in proportion to the height of the atmosphere from which they descend, and to the opportunity that is afforded during the long descent for the molecular forces concerned in crystallisation to accomplish their work deliberately and without interruption. Very perfect snow-crystals are only met with in temperate climates upon rare opportunities, and at long intervals. But they are of very common occurrence in colder climates and more frigid latitudes. Mr. Glaisher's beautiful series of figures were secured during a few exceptionally lucky days of snow-fall that occurred in the neighbourhood of London between February 8th and March 10th in the year 1855. They were represented as they appeared to magnifying lenses after they had been received gently upon chilled fragments of yellow glass. Snow lay upon the ground at this time uninterruptedly during six weeks. On February 21st the thermometer indicated a temperature of 20° at the time when some of the most beautiful of the crystals were observed. The spangles

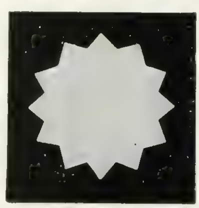


FIG. 8.—THE SPACE BETWEEN THE RAYS FILLED IN BUT THE POINTS STILL APPARENT.

were generally about a tenth part of an inch in diameter, but in some instances they measured as much as three-tenths of an inch across. In ordinary snow-flakes several different kinds of crystals are confusedly grouped, and partially fused together in consequence of their being whirled about and dashed against each other, as they descend through air strata of varying temperature. Under the most favourable circumstances the radiated crystals may be contemplated both growing and diminishing and altering their forms. Many of the most remarkable figures are produced by the softening away of primary points and edges during incipient dissolution, and by the deposit of amorphous accretions upon the primary axes and lines of the crystals.

As a rule, snow falls in this country when the weather is comparatively mild. "It is too cold for snow" is a remark frequently heard amongst the weather-wise, and it is the usual experience that a heavy snowfall is preceded by a rise in temperature. As a result the snow is soft, and the flakes readily unite with each other to such an extent that their star-like symmetry is not apparent to the casual observer. Still, although this symmetry is disguised, it is always present. When, however, we get a cold, dry spell and a light snowfall with very dry flakes, the stellate character of the latter is very evident.

Very fine and lightly deposited snow occupies about twenty-four times as much space as water. The thickness of an ordinary fall of snow collected upon the ground generally represents about as much water as would lie in a tenth part of the same depth. Ten inches of snow, therefore, correspond with one inch of rain. The most accurate way, however, to estimate the quantity of snow that is contained in any fall is to cut a round cake out of the deposit to its full depth by a cylinder of copper, or tin, of known diameter, and then to measure the water that is procured by melting that quantity of snow. This at once furnishes a ready means of comparing the fall of snow with rainfall measured in a rain-gauge possessing a receiving funnel of the same diameter as the cylinder.

The pure white lustre of snow is due to the circumstance that all the elementary colours of light are blended together in the radiance that is thrown off from the surface of its crystals.* It is quite possible to examine the individual crystals in such a way as to detect these several colours before they are mingled together to constitute the compound impression of whiteness upon the eye. The snow is then clothed with all the varied hues of the rainbow. The soft whiteness of snow is also in some degree referable to the large quantity of air which is entangled amidst the frozen particles.

The formation of snow requires that the temperature of the air shall fall lower than the freezing-point of water. But a heavy snowfall needs that the air shall be very moist as well as very cold. The simultaneous presence of these two conditions in the atmosphere does not very frequently occur in the northern hemisphere of the earth, and it is for this reason that heavy snow is so rarely experienced in the countries of Europe. Snow falls very heavily indeed, and often accumulates to enormous depths, on the western side of the continent of South America in latitudes not far exceeding the forty-third parallel, and therefore corresponding very nearly with the position of Rome in the northern hemisphere, because the air is there always heavily laden with moisture when it sinks to the freezing temperature. Snow is scarcely ever seen on the southern coast of Spain. It seldom presents itself on any of the low-lying valleys or plains, although it is commonly seen on the tops

* *See also* "Colour Printing," POPULAR SCIENCE, Vol. I., p. 32.

of the neighbouring mountains in the season of winter.

In all latitudes of the earth snow occurs at high elevations in the atmosphere, although it may not reach the ground in consequence of its being melted as it falls through the lower and warmer parts of the air. Even in equinoctial regions of the earth it is occasionally formed at an elevation of 11,000 or 12,000 feet, and, if there are mountains with tops reaching up as high as this, they catch the snow, instead of allowing it to fall to the warm lower regions where it can be melted. It is for this reason that there are mountains covered with snow all the year round in so many warm latitudes. Such mountains reach up into regions of the air w' ere there is not warmth enough to melt all the snow that is deposited upon the summits. Snow lies unmelted all the year round at the level of the sea within fifteen degrees of the earth's poles: that is, in latitudes higher than 75°. The area of perpetual frost is, however, not included within an exact circle traced round the pole. In the northern hemisphere it extends a little farther from the pole in the direction of the Pacific Ocean than it does towards the Atlantic, and about the meridian of Iceland. There is thus a somewhat irregular frost-cap, of something like 1,200 miles across, fixed over the poles of the earth. In advancing from the outer limit of this polar region of the globe towards lower and warmer latitudes the position at which perpetual congelation occurs rises higher and higher. In England it is above the tops of the highest mountains. In Switzerland it is found at a height a little less than 9,000 feet; very nearly one-half of Mont Blanc is for this reason perpetually snow-clad. Perpetual snow lies at an elevation of 8,950 feet on the Pyrenees, and at 9,500 on the Apennines and upon Etna. It is found at 14,000 feet on Ararat, at from 16,000 feet to 18,400 feet upon the Andes of Bolivia, at 6,000 feet upon the Andes of Patagonia, at 15,800 on the equatorial Andes, at 19,500 feet on the northern side of the Himalayas, and at 15,500 feet on the southern side of the same giant range. Mont Blanc and its associated peaks, have a covering of perpetual snow descending to nearly 7,000 feet below the highest summits.

FIGS. 9, 10, 11, 12.—MORE COMPLICATED SNOWFLAKES, WITH DELICATE FERN-LIKE TRACERY.
These are only to be seen in very dry, light snow.

The snow, however, which lies in this way upon the tops of lofty mountains all the year round is perpetual only in a particular and limited sense. It is not everlasting snow. The phrase "eternal snow," which is occasionally used by the poets, is not scientifically correct. No snow is eternal or everlasting in the proper sense of these words. Snow is always present, but it is not the same snow. That which falls upon the highest summits of the mountains glides slowly down the grooves and valleys of their sides. In the illustration (Fig. 13) which represents the mountain system of Mont Blanc, snow-fringes, or rather ice-fringes, are seen hanging low down into the valley of Chamouni, which bounds this grand cluster towards the south. It is from

amidst these that the vast ice-stream, which is known as the Mer-de-Glace, descends like a frozen river out of the heart of the snow-fields above. These descending streams of consolidated snow are spoken of as glaciers. They are composed of hard ice at their lower parts, and of vast, gathering snow-beds above. The hard, icy state of the frozen mass below is to some extent due to the compression to which it is there subjected. The snow clings to the rocky sides of the gorges and ravines with considerable tenacity, and it is accordingly squeezed by the weight of the masses pressing down from above. But although the first result of the pressure is to render the snow compact and hard, the ultimate result is of an entirely different character. When the pressure has increased to a very considerable extent, it softens even the hardest ice into a kind of yielding paste, which is pushed through the winding grooves and narrow gaps, and over resisting obstacles that stand in its path. As soon, however, as it is released from the severe pressure, the softened ice returns to its original hard consistence. It is by this instrumentality that the hard, rigid ice is forced through curving and rounding channels, and along alternately widening and narrowing beds. It becomes soft and plastic where it is compressed, but is brittle and easily worn into gaping fissures and chasms, wherever it is extended instead of being squeezed in. The "crevasses," or cracks, of glaciers are always found in those portions of the ice-stream where the frozen mass is freed from direct pressure, and exposed instead to tensile strain, such as of necessity occurs in passing down the steep declivities so

Photo: G. P. Abraham & Sons, Keswick.

FIG. 13.—VALLEY AND VILLAGE OF CHAMOUNI (OR CHAMONIX), WITH MONT BLANC IN THE BACKGROUND.
Chamouni lies fifty three miles E.S.E. of Geneva, at an elevation of 3,400 feet above sea level.

common to high mountains. The first suggestion of the softening of ice under pressure was made by Faraday, in 1850, in consequence of his noticing that whenever two pieces of thawing ice are pressed closely together they invariably freeze at the surfaces of contact into one continuous mass. As a matter of fact, the temperature at which water freezes is altered by strong pressure. Greater degrees of cold are required to convert it into the solid crystalline state when it is strongly compressed than when it is free from such influence. Sir William Thomson proved by direct experiments that if a mixture of ice and snow is very forcibly squeezed it becomes colder and colder as the pressure is augmented. The heat which is lost from the sensible state during this process is converted into the latent and insensible condition. But as it is so rendered latent, it is used in turning a small portion of the solid ice into liquid water. The water, however, is more incompressible than the ice; it is not, therefore, lowered in temperature to the same extent as the ice. There is, therefore, ice which is colder than 32° in contact with water at the temperature of 32°. The consequence is that the water is immediately re-frozen by the chilling influence of the ice. Dr. Hooker* first proposed that this operation should be termed re-gelation, or re-freezing, and this very apt and expressive designation has since been generally adopted by scientific men. It is this peculiar property of ice—of being softened and melted by pressure, and of immediately freezing hard again when the pressure is removed—which is brought into play in the familiar operation of making snowballs. The portions of snow which are squeezed together by the hand become moistened by the direct agency of the pressure, and then freeze together into a coherent mass when the pressure of the grasp is lessened. The snowball is, so to speak, a miniature glacier artificially manufactured.

The lower extremities or toes of the glaciers melt away in the warm valleys which they finally reach, and are there turned into streams of running water as fresh snow is heaped upon the heights above. The Arveiron, one of the feeders of the River Arve that joins the Rhone just below the Lake of Geneva, issues in this way from the lower end of the Mer-de-Glace. The Rhone itself takes its rise from another glacier of a similar kind, which pours its frozen mass down a steep descent by the side of the Furca pass, at the head of the Vallais. The glacier masses which drape the sides of high mountains are thus always wasting below and increasing above, and the snow masses above are as continually sliding down to supply the consumption of ice that is taking place below. The rate at which the descent of the frozen mass is accomplished depends upon the rapidity of the slope and the obstacles which it has to overcome in its route. But, as a general rule, it does not exceed ten or twelve inches in the day. In some notable instances, this has been ascertained by direct measurement to be about the rate at which the ice of the glacier moves. Whenever the ice glides along a gentle descent not exceeding an inclination of three degrees, and with a fairly open and untrammelled course, it remains smooth and unbroken. But whenever it descends slopes that are considerably more abrupt, it tumbles over in a torrent of broken fragments, with huge cracks and chasms interspersed amongst them in the wildest confusion. The melting extremities of the glaciers of the Alps are generally found at an elevation of between 2,000 and 3,000 feet above the sea. Until recently, one of the glaciers of Grindelwald was the lowest amongst them, and reached quite into the neighbourhood of the

* Now Sir Joseph D. Hooker, late Director of the Royal Gardens, Kew.

gardens and corn-fields of the valley. The Gorner glacier, which is one of the ice-streams that descend from Monte Rosa, terminates in a similar way near Zermatt, in a very grand form of ice-toe, projecting quite into a region of green vegetation. The lower end of the Rhone glacier (Fig. 14) is hemmed round with verdant herbage and bright flowers during the Swiss summer.

The chief snowfall upon the sides of lofty mountains necessarily occurs at, or within, an elevation of 9,000 feet above the sea. The average fall in the year at that elevation may be estimated at about forty feet of vertical depth. Upon the higher summits of very lofty mountains, such as Mont Blanc and Monte Rosa, very much less is precipitated, on account of the greater dryness of the air at those extreme elevations. The white caps of the snow-clad giants are principally preserved by the precipitation upon them of a kind of hoar-frost, partly condensed out of the clouds, and partly derived from the vapours that steam up to them from the large snow-fields below. The actual depth of snow upon the summit of such a mountain as Mont Blanc has not yet been ascertained, but it is very probable that it does not much exceed ten feet. On the lower slopes of such mountains, on the other hand, it often accumulates to a depth of many hundred feet. Cracks opened out into the ice of some of the larger glaciers have been sounded to a depth of 700 feet without reaching the bottom of the frozen mass.

The snow which is deposited upon the highest parts of lofty mountains is very fine and dry. It is a kind of snow-dust. This dryness is due to the rapidity with which every trace of free water escapes in these elevated regions of the atmosphere. Immediately below the comparatively thin cap of dry snow the broad expanse of deep snow begins. But where the one passes into the other there are generally deep gaps or rents, called *Bergschrunde*, caused by the heavier accumulations below tearing themselves asunder from the lighter deposits above by the mere influence of weight. The surface of the snow on these broad and deep snow-fields assumes the state of small grains about the size of hemp-seed, which are ice within and snow without, and which are separated and partially melted by day, but frozen together into connected clusters at night. It is this granular surface-snow which constitutes the "fern" or "névé" of the Swiss mountains. In the lower part of the more massive accumulations water percolates through the upper porous mass, as the surface is melted by the sun, and is then frozen into a foundation of firm, solid ice below. This subjacent ice-bed increases in thickness in the lower stretches of the glacier, until at last compact, solid ice only is found. It is probable that the compact ice of the interior of the large glaciers is always kept at a temperature of about 32° Fahr., and therefore in a state ready to undergo the process of re-gelation. The fractured masses which are tumbled down the more precipitous parts of the glacier bed are almost invariably frozen again afterwards into renewed continuity by the operation of this agency. To adventurous travellers, climbing the snow-mountains, the ice-glacier appears to issue from the broad fields of granular snow, or "névé."

Professor Tyndall showed that even compact and solid ice is primarily formed out of six-rayed star-crystals, very nearly resembling those of snow, but with their angles intimately and closely interlaced together. By skilful employment of magnifying glasses, these can be seen forming in ice that is beginning to freeze, and they can also be traced, by a similar application of optical instruments, in clear, thick ice that is just beginning to melt. The gathering ice-needles upon the surface of

Photo: G. Wehrli, Kilchberg, Zurich.

FIG. 14.—THE RHONE GLACIER.

It is in this glacier that the great French river Rhone has its origin.

water that is about to freeze over must have been observed by everybody.

This method consists in passing a ray of light through a slab of ice at right angles to its surface, a white screen being placed behind. The heat accompanying the light sets up a tendency to thaw in the slab of ice, and the crystalline character of its structure is then apparent. The name of "ice flowers" has been given to the crystals whose presence is thus revealed. By comparing them with the snowflake and the fairy-like tracery upon a frozen window pane, the close structural relationship that exists between the many spangled snowflake, the apparently amorphous slab of ice, and the much thinner sheet of ice upon the window, will be apparent.

The lightness of ice, which enables it to swim upon water, is partly due to the small portions of air which get entangled amidst the ice-crystals as these are grouped into geometrical forms in the act of freezing.

"White as the new-fallen snow" comes almost instinctively to our lips when we wish for a standard of whiteness. The absolute purity of the snow is so generally accepted that the majority of persons have never for a moment considered the possibility of snow being anything else but white. The phrase even passes muster in the grimy byways of our cities, where the snowflake must and does bring to the ground with it quantities of impurities.

The phenomenon of red snow does not excite the wonder of those privileged to behold it as it used to do. When it was first seen it created something like consternation. The powers of darkness had, it was declared, been interfering with the workings of ordinary everyday nature, and it did not take long for the excited imagination of the peasantry of Savoy and the Swiss Alps to discover in the peculiar colour a likeness to that of blood, and to foresee in the coming of the blood-red snow an ominous foreshadowing of the shedding of human blood. The explanations of science, that the unwonted colour is due to the presence of a unicellar alga of exceedingly minute proportions, in time allayed all these superstitious fears, and the once fearsome red snow is now relegated to its proper place as an interesting, but harmless, natural phenomenon devoid of any ominous forebodings for the human race.

It was Dr. Saussure who first observed the red snow upon the mountains of Savoy—or, at least, it was he who first described it, as far back as 1760. Since then its presence has been notified in the Swiss Alps, parts of the Tyrol, the Pyrenees, the Carpathians, northern Scandinavia, Greenland, and, to include the New World, on the Sierra Nevada in California. The Crimson Cliffs of the rocky coasts of Greenland owe their name to the red snow which the explorer Ross found covering them in 1818; indeed, Greenland has long been remarkable for the peculiarly rich colouring of her red snow.

From a scientific point of view the only peculiarity about the presence of this wonderful little alga, to which the name of *Sphærella nivalis* was given by Somerfelt, is that it should be found living and multiplying in conditions where the temperature is so low that we should expect growth to be at a standstill. Examination of the tinted snow reveals the fact, however, that it is only the topmost layers in which the Sphærella is to be found. Also it is most numerous where the warmth of the summer sun has melted the snow to some extent.

When the single cells which compose the individuals in this curious alga are placed under the microscope they are found to be of two forms, as shown in the accompanying figure. The round cells are filled with protoplasm, contain-

ing chlorophyll, but the green colour of the latter is hidden by a rich red pigment, which really gives the red hue to the whole sac, and when these sacs or cells are present in any numbers to the snow itself. The second form, also displayed in the sketch, is oval in shape, with two cilia, or lashes, at the narrower end. The contents of these oval are the same as those of the spherical cells, but the constantly rotating cilia of the former gives this form of the organism powers of locomotion that the latter does not possess. The round cell may be regarded as the plant proper, which upon the partial melting of the snow sets to work to propagate itself. Its protoplasm repeatedly divides until a number of daughter cells (2, 4, 6, or 8) are formed. Then the parent cell ruptures, and the swarm of spores, or young cells, escape to enjoy a brief period during which they can move about by means of their cilia. Finally they become more rounded, lose their cilia, and settle down into the fixed respectability of Sphærella maturity. Occasionally two of these motile cells, not content with this very ordinary consummation of their life's work, agree to join forces, coalesce, and develop into a sexually formed spore.

Much more of interest might be said about the doings of this little alga, one of the lowliest of all living things. At present, however, we are only interested in tracing its connection with the once mysterious red snow, and we have found that we have managed to explain this phenomenon without having to attribute it to powers that be not of earth.

FIG. 15.—*SPHÆRELLA NIVALIS.*
A unicellar alga that gives red snow its colour.

SNAILS AND SLUGS.

DISMISSING for the moment all early prejudice against the family to which it belongs, let us begin by scrutinising the exterior aspect of that full-grown specimen (Fig. 1) of the Common Garden Snail (*Helix aspersa*), which is going over the ground at the top of its speed on the way to the cabbage-bed. On picking it up one naturally observes that it, roughly speaking, consists of two parts—body and shell. The shell (Fig. 2), concerning which we shall have more to say as we go on, is a familiar object to all; it is strong, light, translucent when the body has been removed, and prettily marked with streaks and zigzags of brown and yellow, varying in different individuals both in tint and details of pattern. The "lip," or edge of the aperture, is slightly reflected, thus giving strength to this the weakest part of the shell, which, elsewhere, owing to its curved walls, will submit to considerable pressure before yielding. Gradually, as we have been speaking, the inmate has recovered from his surprise at his novel situation, and with horns extended to their uttermost is vainly seeking some resting-place for the sole of his foot, permitting us to see that, while the skin of the upper part of the body is covered with closely set wrinkles, the under surface is perfectly smooth and pliant, enabling the creature to make use of it as a sucker when climbing up the plants on which it feeds. This foot is composed of strong muscular fibres interlacing one another, and by the successive motion of its parts the animal is able to glide slowly along.

It is an interesting, not to say a pretty, sight to watch the under surface of the foot, either of a slug or snail, in motion, and one which may readily be witnessed by inducing the creature to crawl on a piece of clear glass. A hollow glass cylinder, such as the chimney of a lamp, is preferable to a flat sheet, as it affords greater facilities for close inspection and more ready handling. Having placed the slug or snail inside the tube, wait till it has got hold with its sucker-like foot, and then turn the glass round so as to bring the under side into view. So long as the animal remains at rest there is nothing in particular to attract one's attention; but the moment the creature begins to move a wonderful change takes place. The first impression is that there must be a hollow channel along the centre of the foot through which a foaming torrent is rushing pell-mell from the tail towards the head. Such, it is scarcely necessary to add, is not the case, and the torrential appearance is solely an optical illusion, due to the successive action of portions of the muscular foot in propelling the animal forward. To understand the nature of this movement clearly, take the case of a caterpillar when crawling. First the hinder portion of the body is drawn up, forming an arch, then the feet in front of the arch are successively raised and those behind set down, causing the arch to move forward towards the head, though the parts of the body maintain the same relative position. By the time that the first loop, or "wave," in the caterpillar's body has reached its head, which is at once stretched forward, another "wave" has commenced at the tail; and so on. Now, the motion in a snail's foot is just the same, only the "waves" do not affect the whole body, as they do in the caterpillar, and they follow each other so quickly as to give rise to the appearance of flowing liquid. The margins of the foot do not participate in this motion,

but have a gentle, lateral, undulating movement of their own. This motion of the muscular fibres of the foot is under the control of the animal so far as starting and stopping are concerned; but the actual motion itself appears to be automatic, and comparable to that of a locomotive engine when the driver turns the steam on or off, leaving the actual work to the mechanism itself. Reverting again to the upper surface of the snail's body, we notice the thick, tough, wrinkled skin, which is composed of transverse and longitudinal muscular fibres unsupported by any internal framework or skeleton, thus allowing the mollusc to vary its shape and expand or contract at will. Moreover, we see that this dermal envelope is kept constantly moist by the slimy mucous matter that renders these creatures so unpleasant to the touch. The glands that secrete the slime are buried amongst the muscular fibres of the skin, but there is also a large one within the body; and an astonishing quantity of viscid slime can on occasion be poured out by the united action of these glands.

As the slug or snail crawls along it leaves behind it a little of this mucous stuff, which, when dry, forms that glisten-

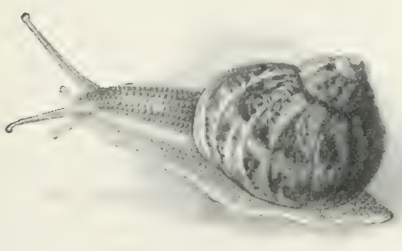


FIG. I.—THE COMMON GARDEN SNAIL *(HELIX ASPERSA)*.

ing film on the wall or ground spoken of as its "trail" or "war-path." Certain of the slugs make another use of this tenacious material, for, taking advantage of its cohesiveness and the rapidity with which it hardens, they will lower themselves by a fine thread of it from a tree or bush to the ground. Some species, as, for instance, *Limax arboreum* (see Fig. 6, 8), can even re-ascend the gelatinous filament, a feat which in arboreal life must often stand them in

FIG. 2.—SHELL OF THE COMMON GARDEN SNAIL, SHOWING "LIP."

good stead. As the object of our inquiry has drawn in his horns, we must, if we would learn anything about them, follow them whither they have retreated; more especially since, aided by the set of muscles that are attached to the interior of the shell and pass down into the foot, their owner has retired into his habitation, positively declining to be further interviewed.

Having killed the snail in the quickest, and therefore least painful, manner—namely, by immersing it in boiling water containing a liberal allowance of table-salt—the animal can be carefully extracted, periwinkle-wise, from its shell, and a more perfect examination of its structure instituted.

The difference between that portion of the creature habitually protected by the shell and the part exposed when in motion is the first thing that strikes the eye, the skin covering the former being as thin and smooth as the latter is thick and wrinkled. The delicate membranous portion exposed to view by the removal of the shell is technically known as the *mantle*, and plays an all-important part in the snail's anatomy, as it is the shell-forming organ. Where the "mantle" is united to the tough skin of the foot it becomes greatly swollen and forms a

sort of collar, the edge of which may be seen curling round the reflected "lip" of the shell when the snail is crawling along.

The extension of the shell as its tenant grows is entirely effected by this swollen margin of the mantle, which carries the pigment cells, or glands, that secrete the colouring matter forming bands or patterns on the shell. The rest of the mantle is devoid of pigment glands, and merely deposits layers of shelly matter on the interior, thickening and strengthening the habitation. In the same way injuries to the shell are repaired. If only the mouth of the shell be broken, the fractured portion is restored, with all its proper colours and markings, by the collar of the mantle; but if a portion of the spire be destroyed, the breach is closed by opaque, colourless matter deposited by the other parts of the mantle.

The shell so formed is built up of layers of animal matter strengthened by the deposition of calcareous and other earthy matters which the snail derives mainly from plants; these in their turn obtain it from the soil, whence naturally it follows that snails are abundant in limestone districts. The outermost or first layer, called the *periostracum*, is of animal matter; it protects the shell from the influence of the weather, but soon fades and disappears after the death of the animal. This twofold nature of the shell may be verified by placing a portion in water and adding a little acid, when the lime will be dissolved away, and nothing but the membrane, in which the lime was deposited, left; or a piece of shell may be boiled in caustic soda to remove the organic matter, and then the inorganic lime will be left behind. Each layer of the shell was really, according to the opinions formerly held, once a portion of the mantle itself, which became calcified, that is, hardened with carbonate of lime, and was then thrown off to unite with layers previously formed. More recent authorities maintain, almost universally, that the shell is formed by excretion, the particles of carbonate of lime being held together by animal matter. In the parts next to the "periostracum" the lime assumes a crystalline form, and a prismatic layer laid down by the edge of the mantle can be distinguished from the nacreous or pearly layer deposited by its general surface.

A strong, light structure is thus built up, into which the creature can retire at pleasure or retreat for protection from its numerous foes. In the young mollusc the shell is very thin and transparent, and the edge of the mouth shows none of that thickened and reflected rim characteristic of the adult individual.

On the right side of the body, under the collar of the mantle, is the opening which leads into the "pulmonary sac," or "breathing cavity," where the nearly colourless blood is exposed to the purification of the air in countless small vessels that ramify over the roof of the chamber. The floor of the cavity is formed by a thin muscular membrane which separates the respiratory apparatus from the rest of the viscera. The air is changed by diffusion through the orifice. Many water-dwelling molluscs have a similar organ of respiration; but in others the purification of the blood is effected by beautiful plume-like gills. On laying open the visceral cavity from the head along the back towards the anterior extremity, an intricacy of internal organisation is disclosed that will assuredly surprise anyone who sees it for the first time (Fig. 3).

In the first place, let us notice the digestive apparatus. Commencing with the mouth, which is placed on the under side of the head, we find, in the first place, a kind of upper jaw consisting of a broad horny plate, with a very sharp, curved lower edge, and opposed to this is the tongue, armed with recurved spines,

or "teeth," as they are more commonly called. These teeth are set in a muscular membrane and point towards the back of the mouth; they are translucent, glossy, of various shapes, and set in rows forming different patterns, each genus, and often species, of snail possessing its own peculiar arrangement, shape, and number of teeth. This "tongue," *odontophore*, or "lingual ribbon" (Fig. 4), as it is variously termed, serves as a sort of rasp whereby, with the aid of the horny jaw, the toughest vegetable fibres or animal tissues can speedily be abraded. In the common whelk the lingual ribbon is very long and narrow, and is employed by the animal to perforate the shells of other molluscs. Through the breach thus effected the unlucky victim is devoured piecemeal.

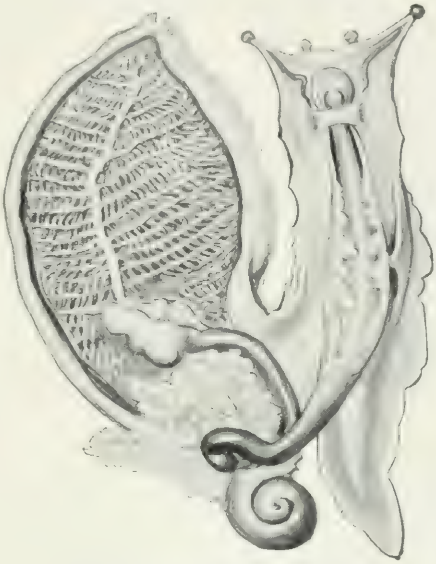


FIG. 3.—THE SNAIL LAID OPEN.
Showing a very intricate anatomy.

In the snail before us, and in the slugs the teeth are very nearly all of a size, and set so closely together as to give the tongue, when viewed only with a pocket-lens, the appearance of being finely marked with transverse striæ; if, however, it be properly prepared and placed under the microscope, it reminds one rather of some marvellous piece of tesselated pavement. There are 135 rows of these teeth in the odontophore of the Common Garden Snail (*Helix aspersa*), and 105 teeth in each row, giving a total of 14,175 teeth in the whole tongue; but this is surpassed in the largest British land snail (*H. pomatia*), where the total is 21,140, disposed in 140 rows of 151 each; whilst in one of the slugs (*Limax maximus*) this number is swollen to 28,800, placed in 160 rows of 180 each! As the teeth in the front wear away their place is supplied by the next in order, fresh teeth forming at the back, to be eventually used in their turn. Behind the mouth, which is amply supplied with salivary glands, we find the œsophagus. This leads down to the stomach, whence the intestinal canal arises, and, coming back again towards the head along the right side of the body, passes through the folds of the liver, terminating just behind the respiratory orifice. The purified or re-oxygenated blood is brought from the pulmonary cavity by a large vein to the heart, which consists of a single auricle and ventricle, whence it is pumped through the body again. The nervous system consists of four important pairs of "ganglia," or nerve centres, closely connected with each other so as to form a collar, which encircles the œsophagus just behind the "buccal" mass which contains the "tongue." The cerebral "ganglia" are above the alimentary canal, and from them nerves proceed to the tentacles, or horns, and to the mouth. The others supply the foot, viscera, and respiratory organ. In this respect, therefore, the snail offers a great contrast to the

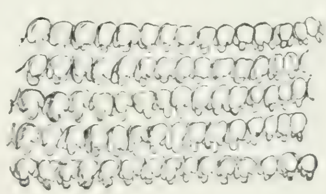


FIG. 4.—THE ODONTOPHORE OR LINGUAL RIBBON OF THE COMMON SNAIL.
There are altogether about 11,000 teeth.

insects, in which there is a nerve centre for every segment of the body.

The extremities of the upper and longer pair of "horns" terminate in a round knob surmounted by a black speck—

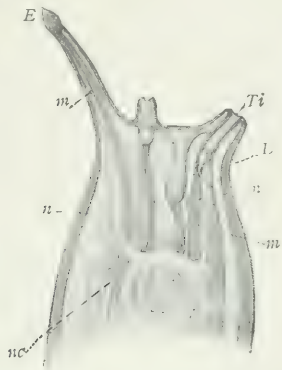


FIG. 5.—DIAGRAM, SHOWING TENTACLES WITH EYES.
E. Eye.
m. Retracted muscles.
n. Nerve to eye.
nc. Nerve collar.
Ti. Tentacle partly withdrawn.

the eye. This, though not so perfect as in the cuttle-fish, is nevertheless sufficiently developed to enable its owner to distinguish, though vaguely, the nature of surrounding objects. The method by which these eye-stalks are drawn into the visceral cavity when danger is apprehended, and thrust out again when the cause of alarm has passed away, is worthy of attention.

Each of these tentacles (Fig. 5) is a hollow flexible tube, whose muscular walls are composed of circular fibres. The special muscle by means of which this tentacle can be drawn in is attached to the base of the eye at the extremity, and passing down the tube, joins the general muscular mass of the foot. It is accompanied by the optic nerve, which likewise passes along the tube, connecting the eye with the cerebral ganglion. When the muscle contracts the tip of the "horn" is drawn inwards, followed gradually by the remaining portion, just as, to quote a well-known example, the finger of a glove can be pulled in and completely inverted. Its protrusion, on the other hand, is effected by the action of the muscles that compose the tubular wall of the tentacle itself. By concentrating the rays of the sun or a lamp on the extended tentacles of a living snail and looking at them through a magnifying glass the extension and retraction of these organs can easily be studied, the action of the muscles noted, and the trouble of dissection obviated. The inferior and shorter pair of tentacles undergo inversion in the same way as the larger pair; but they are destitute of eyes, and serve, apparently, merely as organs of touch, supplemented by the sensitive skin of the creeping disc and body. Where the sense of smell resides in snails is not yet absolutely determined; but that they do possess this faculty we have abundant evidence to prove, and the pedal gland which opens beneath the head is probably olfactory in function. Slugs, too, are attracted by offensive odours, and many marine mollusca, like the whelk, may be caught by animal baits, especially if these be at all "high."

The means of recognising sound is provided by vesicles which are embedded in the substance of the pedal "ganglia." They consist of small, spherical sacs containing a fluid, and minute, calcareous *otoliths*, or ear-stones.

The faculty of taste, if possessed at all, must be very faint indeed, judging from the structure of the mouth and tongue. Nevertheless, a certain amount of discernment appears to be exercised in their choice of diet, since they exhibit a preference for peas and cabbages, and will emigrate or fast sooner than touch the white mustard plant. Some, again, seem to prefer animal food, especially when "tainted," to a vegetable diet.

On turning over an old flower-pot in a damp corner of the garden, one sometimes meets with a number of small, round

FIG. 6. SOME SNAILS AND SLUGS.

1, Clausilia bipunctata; 2, Testacella haliotidea; 3, Geomalacus maculosus; 4, Arion ater (white variety); 5, Helicella virgata; 6, H. barbara, a chalk-loving snail with high spire; 7, H. nemoralis; 8, Limax arborum, one of the tree slugs; 9, Internal shell of Limax maximus.

bodies, soft, semi-transparent, and about the size of small peas. These are slugs' eggs. Their only protection is a tough albuminous envelope. The eggs of snails have a calcareous shell, and in the case of the foreign genus *Strophochilus* they are as large as pigeons' eggs, which they much resemble (*see* Fig. 7). Some species are viviparous, the young snails passing through the early stages of their development within the body of the parent. *Clausilia biplicata* (Fig. 6, 1), a pretty British land snail with a prolonged spiral shell, is a case in point. The eggs of the garden snail, in number about 100, are usually laid in the summer; the young snails appear at the end of from fifteen to twenty days, and by the autumn have attained about a third of their full size. When a considerable addition is to be made to the shell, the snail, keeping the orifice of the latter directed downwards, retires below the surface of the ground. Here it is less likely to be disturbed or injured while the new portion of the shell is still soft.

FIG. 7.—*STROPHOCHILUS* AND ITS EGG.

During the winter, snails hibernate, burying themselves with the shell mouth upwards, or they retire to sheltered nooks, in either case closing the mouth of the shell with a hardened layer of mucus, or "slime," known as the *epiphragm*.* On the return of the warm weather they burst from their confinement, and complete their growth within the end of their first year. Their lives, however, are short, and they do not in the natural state seem often to survive the second winter; but in confinement they will attain the advanced age of six, or even eight, years. Perhaps one of the most interesting examples of long-endured compulsory confinement to its shell was that undergone by one of the Desert Snails (*Helix desertorum*) from Egypt, which had been stuck on a tablet in the British Museum in March, 1846, and was found to be still alive in March, 1850.

Instances of malformation in the shell of our friend are tolerably common, snails, like other mortals, being liable to accidents. Cases of monstrosity, such as reversed or left-handed varieties, where the shell has been wound the wrong way, have occasionally been met with, in which case the relative positions of the internal organs are reversed too; but the most extraordinary specimen of abnormal growth is the curious cornucopia-like variety now in the British Museum, of which a sketch is presented in Fig. 9.

The capability of reproducing lost or damaged portions of the body is another characteristic of the snail, and one which it possesses in common with many other creatures both higher and lower than itself in the zoological scale. The experiments of the Abbé Spallanzani show that the tentacles, if cut off, can be reproduced, eyes and all, at the end of about two months. Even the removal of the whole head seems to cause but temporary inconvenience, as it is entirely and perfectly reproduced after a little time, during which the mollusc keeps close within his shell.

The foregoing remarks on the Common Garden Snail apply, with but slight exceptions, to all his intimate relations.

* The Edible Snail (*Helix pomatia*) derives its name from the very thick and solid "epiphragm" it forms, *poma* in Greek signifying "lid."

Prominent amongst these are the handsome Yellow-banded Snails so common on all hedgerows, and by far the most gaudy of the British *Helices*. There are two distinct species (at one time regarded as varieties) of this mollusc. In one (*H. hortensis*) the lip of the shell is white;

FIG. 8.—THE ROMAN OR EDIBLE SNAIL (*HELIX POMATIA*).
At one time held in high esteem as a remedy for consumption.

in the other (*H. nemoralis*) (Fig. 6, 7) brown. Of these, the white-lipped form appears generally to be the smaller.

The bands with which this shell is striped vary in number from one to five, and, though generally of a chocolate-brown colour, sometimes appear quite colourless on the yellow shell. Then there is (Fig. 8) the large Roman or Edible Snail (*H. pomatia*), said to have been imported into this country by the Romans. It is renowned both as a delicacy and on account of its reputed virtues as a remedy in cases of consumption, which it is said has in several instances been entirely cured by a regimen of the mucilage from these snails. On the Continent the Roman Snail is considered a great delicacy, but the Garden and Yellow-banded Snails are the ones more commonly eaten. A snail feast is held annually in the South of France on Ash Wednesday, when large numbers of them are consumed. An analogous custom is said to prevail in our own country amongst the operatives of Lancashire and at Newcastle. The Roman Snail is very local in England, and confined to the southern portion of the island. It is very plentiful at Reigate, and after a smart shower may be seen in abundance on the steep chalk face north of the town. Another local snail is the prettily banded *H. pisana*, only to be found in Cornwall, South Wales, the south-east of Ireland, and Jersey; whereas in Spain and Southern France it is common, so that it would be interesting to know how it came to these isolated spots in England, more especially as it is unknown in Northern France.

In direct contrast with the scarcity of this last species is the abundance of such forms as the Kentish Snail (*H. cantiana*) and the pretty little species, white banded with black, *H. virgata*, that with two or three others are so plentifully scattered over the grassy slopes of the South Downs. These last, with other species, are alleged to be the cause of the superior flavour of South Down mutton, as the sheep must infallibly consume them in large quantities when cropping the short grass. Altogether in the British Isles there are some thirty species (if we include their first cousins of the genus *Vitrea*), all allied to our friend the Common Garden Snail.

Intermediate between these snails and the slugs comes a curious little genus, *Vitrina*, represented in this country by a single species that unites in itself characteristics typical of its relations, so to speak, on either side. Thus it possesses the shield and conspicuous respiratory orifice of the slug along with the whorled shell of the snail. It is a very pretty little mollusc, with a thin, transparent, glossy shell that is more or less soft when the animal is alive, but becomes brittle after its death. It dwells principally amongst moss and dead leaves, and, though professedly a vegetarian, likes nothing better than a good meal of an animal nature.

Slugs, to which we next come, present, as everybody knows, one very marked difference to the snails in that they are devoid of any external shell; neverthe-

less, the majority of them possess a small shell, or the rudiments of it, concealed beneath the oval prominence on the back —the mantle, frequently termed the "shield."

In the important features of their anatomical structure these homeless molluscs closely approximate to their householder brethren; but in the one case, as we have already seen, the viscera are separate from the foot, and are carried coiled up on the back and enclosed in a shell-secreting mantle; in the other these organs lie along the back under the same tough, muscular skin that clothes the foot, the mantle being reduced to a mere patch on the back, secreting calcareous matter on the inner and not the outer surface. It is significant that in most molluscs the primitive shell, temporarily produced in the embryo, is an internal one, formed in a pouch or invagination of the mantle, called the "shell gland." Later on in the development a secondary and external shell replaces the first. The want of a capacious shell as a protecting stronghold in times of danger is nevertheless made up for to the slug in the additional facility with which, freed from such encumbrance, it can contract, and retreat into cracks and crannies whither it would be impossible for the snail to creep. By way of proving the rule that slugs have no external shell, three British members of one interesting family carry a small, ear-shaped, calcareous shell stuck on the posterior extremity of the body, where it is situated nearly over the respiratory orifice. Why the mantle, with the attendant breathing apparatus and shell, should be posted so far back in this genus (*Testacella*) (Fig. 6, 2), instead of being situated well forward, as in the rest of their tribe, is not at first apparent. When, however, the habits and mode of life of these eccentric species are taken into consideration this peculiarity of structure is no longer mysterious. The *Testacellæ* are carnivorous, and feed on earth-worms, which they fearlessly pursue through the dark and tortuous passages of their underground burrows, and which they will devour even if many times their own length. Now, were the respiratory orifice placed as in the rest of their race it would be liable to become choked up with particles of earth falling from the sides of the worm's burrow. Nor would a protecting shell in such a position be of the smallest use, as it would catch against everything, if it did not positively prevent the animal altogether from entering the narrow passage. Moreover, were the burrow a narrow one, and the slug full sized, the animal would inevitably be suffocated, because no air could get to the pulmonary cavity, since the elastic, slimy body would completely block the way. Placed as we find them, the slug is enabled to make full use of these organs: it can breathe freely, the orifice being quite in the rear; it is in no danger of being choked by earth, for the shell guards the entrance of the cavity and serves, in addition, as a buckler to shield the creature from hostile attacks in that quarter, without hindering its progress. In other words, to put the matter in its proper light, those *Testacellæ* which were

FIG. 9.—A CURIOSITY IN SNAIL SHELLS.
The whorls do not touch each other.

the better able to breathe in the narrow track, and were best protected, were also the better qualified to pursue their prey, and therefore to live and perpetuate their species.

The peculiar food of the *Testacellæ* has brought about special modifications of structure in the mouth and tongue. The former is exceedingly wide and capacious, the corners when it is at rest protruding till they almost suggest a third pair of tentacles. The tongue is correspondingly large and wide, with about fifty transverse rows of teeth (Fig. 10). In each row are fifty-one slender teeth barbed at the points, which, as in other molluscs, are directed towards the back of the mouth, aiding in passing the food on to the gullet, so that the more the worm struggles to free itself the more surely does it become engulfed.

The other slugs found in this country belong to two families, *Arionidæ* and *Limacidæ*. Most people have met with the large black slugs (*Arion*) (*see* Fig. 6, 4) when taking their walks abroad in the coolness and dampness of an autumn evening, and there are few who do not know the smaller species of the garden. The genus *Geomalacus*, known also upon the Continent, is found in Ireland (Fig. 6, 3). There are several British

FIG. 10.—PART OF ODONTOPHORE OR LINGUAL RIBBON OF *TESTACELLA*.
There are about 50 transverse rows of teeth.

species of *Limax*, the most familiar of which is the Great Grey Slug (*L. maximus*), with his black stripes and other decorations, who, in company with the Yellow Slug (*L. flavus*), haunts the dustbin and cellar, feeding on the refuse matter from the table. The latter has gained the reputation of being able to clean bones well, and of exhibiting a liking for cold potatoes.

Who, too, that keeps a garden has not had cause to mourn the depredations of the smaller but more destructive *Agriolimax agrestis?* This species is, unfortunately, very prolific, and brings up several families in the year.

To trace the garden snail's relations in the opposite direction, away from the slugs, would be to attempt to compress the materials of a manual into a few pages. The kith and kin of our *Helices* may be found figured and described in many a work, or sought for practically in the damp spots in which all snails love to dwell. For moisture is to them a necessity, and the amount of water they will take into their systems is astonishing. Experiments made in this direction on *Helix pomatia* tend to show that the quantity of water it can absorb when in a healthy state exceeds in weight that of the animal itself, and it appears to be taken thoroughly into the system.

The genus *Helix* is an exceedingly large one, and comprises some thousands of known species, distributed all over the world, extending northwards as far as the limit of trees, and southwards to Tierra del Fuego. The examples common in Britain are spread largely over the continent of Europe, and many of them extend into Northern Africa; whilst some few are known to occur as far east as Siberia, and others are found even in the United States.

The Yellow-banded Snail with the brown lip has been seen even in Greenland, in company with the Grey Slug (*Agriolimax agrestis*).

Doubtless, with the increased facilities of intercommunication between different countries, the present distribution is gradually changing. Species accidentally

introduced into this country, or imported from it to others, will, if they meet with conditions suitable to their development, in process of time become acclimatised. In this way *Testacella Maugei* may have been imported into England upon plants, for its presence was first recorded at the beginning of the nineteenth century on some gourds in a nursery near Bristol. It is now widely distributed in this country. Of the suggested introduction of *Helix pomatia* we have already spoken. Its shells have, however, been found in deposits which may be pre-Roman. As it has not yet been found as a fossil, *H. pisana* is probably another intruder. Our exports are more numerous, and appear to have gone almost exclusively to the United States. Statistics show the successful trans-shipment to that country of three species of slugs (*Arion hortensis*, *Agriolimax agrestis*, and *Limax flavus*), and two snails (*Vitrea cellaria* and *V. radiatula*). The last named went over in some casks.

It is also probable that *Hygromia fusca* was transported into Northern France from this country about the beginning of last century, as it was not observed there till 1838, and then only in the part nearest to England, the first specimens recorded being found in the neighbourhood of Boulogne.

Some hundreds of species of *Helix* and several slugs are known to us by their shells as occurring in the fossil state. With but one or two exceptions, none found in Britain is older than the Eocene period. *H. Dawsoni* has, however, been recorded (with *Vertigo Murchisoniæ*, a minute land snail) from the Lias.

Land snails, nevertheless, made their appearance at a much earlier date in the world's history, for the coal measures of Nova Scotia have yielded specimens of a species of *Zonites* (or closely allied form) as well as examples of a shell generically undistinguishable from the "Chrysalis Shells" (*Pupa*) of to-day.

A great number of our living Helices are found fossil in the upper Tertiary beds, such as the Pleistocene deposits in Essex, associated with forms now living on the Continent, but which have become extinct in Britain. Curiously enough, though the Tree-snail (*Helicigona arbustorum*) and the Yellow-banded Snails (*H. nemoralis* and *hortensis*), with their smaller brethren, are common in these fresh-water marls, it is only recently that specimens of the Garden Snail (*H. aspersa*) have been recorded of earlier date than that of the Roman occupation.

Numerous and prolific as slugs and snails are, their numbers are largely held in check by many powerful foes, leaving man entirely out of the question. Birds devour large quantities of them. Ducks especially thrive on them, and are capital scavengers of an infested crop, when the plants are not too young.

Everyone is familiar with the stone altar on which the thrush sacrifices his victims, and has seen how, when he has found a choice snail, he flies off with it to the sheltered nook where this stone lies, and raising his beak aloft brings the shell down with all his force on the stone, blow succeeding blow till the fortress is battered in and the inmate secured (Fig. 11). This process being repeated with each fresh capture, the ground around the stone is soon strewn with fragments of shell. The lapwing has a very similar habit, and blackbirds, rooks, and starlings all enjoy a snail feast, swallowing the smaller forms shell and all. The hedgehog also helps to thin their ranks; whilst frogs and toads, together with slow-worms, consider slugs most luscious morsels, and treat them accordingly.

Several insects, including the well-known glow-worm, deposit their eggs in the snail's body, the grubs, when hatched, feeding on and finally destroying their

host. To complete the list of enemies comes a fungus that attacks the eggs of the Grey Slug (*Agriolimax agrestis*), sometimes even before they are extruded from the body of the parent. Altogether apart from these internal plagues is the curious little being (*Philodromus Limacum*) which especially infests some of the slugs. These acari (or mites), for such they are, appear to reside principally in the breathing cavity of the mollusc, though what they do there, or whether they penetrate farther still, has not yet been satisfactorily determined. At intervals they issue forth, and may be seen running races with impunity all over the slippery body of their apparently unconscious host, the peculiar structure of their feet enabling them to keep their footing perfectly on the surface of the slimy mucus. To safely capture one alive for microscopic purposes is by no means easy, for the least rough handling destroys them. They laugh at water, and elude even the tenacious grasp of Canada balsam, but are killed by spirits.

FIG. 11.—THE THRUSH'S ALTAR.

Picking up the snail in its beak, the bird hammers it against a stone till the shell is broken, when the luckless occupant can be extracted.

NEW PLANTS FOR OLD—THE RISE AND PROGRESS OF THE TUBEROUS BEGONIA.

1. BEGONIA DAVISII }
2. B. PEARCEI } TWO OF THE PRINCIPAL PARENTS.

3. LORD CHELSEA }
4. M. A. HARDY } SOME OF THE PROGENY.

NEW PLANTS FOR OLD.

By ALEXANDER S. GALT.

IF there is one thing more than another that is forced upon the consciousness of the student of plant life, it is the reality of the law of change. The working of the same law is graven upon the rocks and voiced by the ever restless sea. We read it anew in ourselves and in the plants around us. "Times change, and we change with them," might well be the epitaph of the universe.

And this change is true evolution. The one dominant thought that came to the Western races of mankind with the nineteenth century was this great doctrine of evolution; and, although it has been fiercely combated in various quarters, its main provisions have not been affected. Nay, are they not proved day by day to those who have eyes to see and ears to hear?

FIG. I.—*SOLANUM TUBEROSUM*, THE PARENT OF THE CULTIVATED POTATO.

"And man planted a garden." Even here we see Nature working. In taking the wild plants from their native habitats and placing them amidst new surroundings, it may at the first blush seem as if man had directly interfered with Nature's movements; but as we probe a little deeper into the actualities of the case we shall find that this is not so. It might seem, perhaps, that man's methods are arbitrary and artificial, and it is true that they differ in some respects from Nature's; but this difference is one of degree only, and not of kind. Man is in a hurry, and Nature is not. Man, the individual, has only a short span of "threescore years and ten," perhaps not more than half of which is really available working time. Nature has her æons of years wherein to compass that which she pleases.

What wonder, then, that man is in a hurry? He sees certain plants around him which appeal to him by the beauty and fragrance of their flowers, the delicious flavour of their fruits, or the valuable food products which their other parts may furnish. It is natural that he should wish to develop these economic products of the earth to the full. To this end he has planted his garden, and ever with this aim he tends his plants, step by step improving them, from his own standpoint—that is, increasing their powers of usefulness to him and his. Flowers have to be made larger and brighter in hue; even their very shape, as well as the habits of the plants which bear them, may have

to be changed. The size of fruits must be increased, flavour and appearance enhanced, and the fertility of the plants themselves augmented.

There are three "tools," as it were, which he uses in his work, and they may be tabulated thus :—

(1) Cultivation.

(2) Selection.

(3) Cross-breeding and hybridisation.

By means of the first he supplies rich soil, suitable moisture conditions, and in many cases favourable temperatures, the while he guards his *protégées* religiously from all interference on the part of other usurping plants and the not too favourable attentions of insect and fungoid parasites. In doing this the cultivator has given these plants a better chance to do well than they had in their native wilds, for then they had to grow, not where they wished, but where they could. Driven from the fertile spot by stronger usurpers, they had to flee to the less fertile place—or die, and death was not their choice.

Photo kindly supplied by Messrs. Sutton & Sons, Reading.

FIG. 2.—*PRIMULA SINENSIS*, THE PARENT OF THE CHINESE PRIMULA.

This is the closest approach to the original species that the botanist has been able to discover. Compare with Fig. 3.

Now, as the environment changes the structure of the plant changes too, for, compelled to take up its abode in a certain position, the plant is constrained to make the best of things, and so arrange its parts that they shall enable it to get the most out of what that position has to offer.

Take, then, the wilding transferred to its protected surroundings. The constant and liberal supply of food affects the colour and size of its flowers and fruits. Sheltered from the cold, its flowering season may be lengthened, until, instead of blooming for a week or two only, it may produce its blossoms in every month of the year. It is quick to note the change in environment. Then the alteration in structure and behaviour follows.

Now the selector steps in. The individual plants do not all change in exactly the same way, at exactly the same time, for there are degrees of precociousness even here. While some will apparently not be affected, others will show a tendency to throw larger flowers or fruits. There may be a richer hue here, or an entirely different tone of colour there. And amongst it all the selector takes that which he thinks most fit—that is, those which most please him—and hallmarks them as the progenitors of the succeeding generation. But his business is not alone to save. His also is the power and his the business to destroy, and he does it thoroughly and with a will. The best only have to be saved: the rest must be ruth-

lessly destroyed, for a new plant is in the making.

By the stimulus of cultivation, then, the advent of change is hastened, and by continual selection, patiently and consistently carried on for generation after generation, the breeder of the new race forges link by link the chain which leads from the old to the new. Not infrequently *he destroys the intermediate links*, and we must be particularly careful to note this, for it is the key to much that is mysterious in plantdom.

By means of the third tool—cross-breeding and hybridising—the florist is able to combine in one organism desirable features that may be present in two or even more plants. Thus, when he desires to get a plant of dwarfer stature he may cross it with a plant of another *species* or variety which is itself dwarf, this dwarfness being in some degree transmitted to the offspring. Or it may be a new colour that he wishes to get amongst his flowers, or a new flavour in his fruits. Finally, this cross-breeding may go on for a considerable number of years, until at last plants are obtained which have blood of a number of species in their veins, and have to some extent inherited the characteristics of each species, although in a modified degree. We thus see that the law of heredity comes strongly into play here, and it is only by taking advantage of it that the plant breeder is able to give us new plants for old.

So far, then, we see that the stimulus of cultivation *plus* selection of suitable

Photo: Sutton & Sons, Reading.

FIG. 3.—THE MODERN CHINESE PRIMULA.

Note the great increase in the size of the flowers and the decided tendency to doubling.

forms, and the mixing of these by means of cross-fertilisation, give us in the end a plant which may be many degrees removed in character, appearance, and behaviour from its ancestors—that is to say, those plants which were first admitted to the charmed circle of the garden.

If we turn for a moment to the illustrations, we shall see at once how much progress has been made. The coloured plate shows us examples of the modern single and double tuberous begonias, which are now in such high favour. Side by side with these specimens of the plant breeder's skill are placed for comparison some of the original species with which he worked—viz. *Begonia Pearcei* and *B. Davisii*.

We do not need botanical skill to see the difference in size and appearance of bloom. The regular double flower, with its multiplicity of petals, has only been produced at the expense of the essential organs of reproduction — the *stamens* and *pistil*. They have gone that the double flower may have being. Again, look at what is probably the most popular flower of modern times—the chrysanthemum. Originally a small flower* with a single row of yellow guard florets, *Chrysanthemum indicum* has got far away from its ancestry. A few years ago Mr. Watson, of Kew, had the curiosity to count the number of "ray florets" in a flower of that grand white variety, Madame Carnot, and found that it contained no fewer than 800. Compare this with the eighteen or twenty which the original plant was able to boast of, and we see how great has been the change. Other changes there have been, and, as the physiological botanist well knows, the constitution of the plant has had to pay a penalty for the constant involution, but the difference in the flower is the most striking of all to the popular mind—it is so self-evident.

FIG. 4.—THE OLD PLANT, *CHRYSANTHEMUM INDICUM.*

The parent of the numerous modern varieties of chrysanthemum.

I might go on to multiply instances of the movement that has been made away from old types, but the foregoing are sufficient for our purpose. We see quite clearly that in causing his *protégées* to develop along lines which he has laid down for them, the purveyor of "new plants for old" has only taken advantage of the natural tendencies of the plants towards change. Early in his botanical career the student is taught that there are several important lines along which development may take place in Nature. We may sum them up here, without going too much into detail, as :—

* The word "flower" is used here in its popular, not its botanical, sense. Strictly the chrysanthemum, like the daisy, dahlia, and members of the natural order *Compositæ* generally, bears a head of many flowers, each so-called petal of which is really a small flower, or *floret*.

(1) Suppression of parts.
(2) Multiplication of parts.
(3) Cohesion of parts.
(4) Adhesion of parts.

These may seem very simple, but between them they may and do embrace a tremendous amount of variation. In the double flower we have seen an instance of the *suppression* of *stamens* and *pistil* and the *multiplication* of the *petals*. Our double roses, carnations, and camellias have all been made in this way. The petals of the buttercup are *free*, those of the primrose are joined to each other, *i.e.* we get *cohesion*. In the buttercup, too, the *stamens* are not joined to any other part of the flower, but are directly inserted upon the point of the main axis, called the *floral receptacle* or *thalamus*. In the primrose the stamens adhere to the petals—*i.e.* we get an instance of *adhesion*.

We may define *cohesion* and adhesion by saying that the former is the term used to denote the union of parts of the same series to each other—*e.g.* petals to petals, stamens to stamens; and that *adhesion* is the term applied to the union of parts of one series to parts of another—*e.g.* stamens to petals.

Now, by taking advantage of natural tendencies, and, it may frankly be said, by stimulating them, the plant breeder is able to work wonders, and to so modify a flower that it bears but a faint resemblance to its progenitors.

FIG. 5.—THE NEW CHRYSANTHEMUM, LORD LUDLOW.

The growth of the gloxinia, shown pictorially in Figs. 6, 7, 8, 9, and 10, constitutes a most interesting chapter in new flower-making. Like many other floral pets of to-day, the gloxinia is of hybrid origin. The principal parent is, however, *Sinningia speciosa* (Fig. 6). A peep at

the pictures will show the various stages through which the flower has passed. First solitary and drooping, the blooms gradually raise their heads until in the finished product they are boldly erect. Yet even here it cannot be said that finality has been reached. Increase of size and new colours are still being striven for; but, taking the original sinningia and the new gloxinia upon their merits to-day, and without any reference to the line of modification that connects them, the botanist would be obliged to acknowledge them as distinct.

Photo: Messrs. Sutton & Sons, Reading.
FIG. 6.—THE PARENT OF THE MODERN GLOXINIA (*SINNINGIA SPECIOSA*).

The China aster (*Callistephus hortensis*) is known to everybody, for has it not been an inmate of cottage gardens for many a year? It will be seen, upon looking at Figs. 11 and 12, that precisely the same fortune has befallen it at the hand of man as in the case of the chrysanthemum—viz. that the short florets of the disc have given place to the florets of the ray,* thus producing an apparently double flower. It will be noticed that both suppression and multiplication have had a good deal to do with the modification of both chrysanthemum and China aster. In the case of the Chinese primula mere increase in size has played a great part, but with it there has been some multiplication of petals and a notable decrease in the stature of the plant, which, as far as its modern representatives are concerned, is a very squat and compact individual.

Photo: Sutton & Sons, Reading.
FIG. 7.—THE GROWTH OF THE GLOXINIA.
The individual flower is very small and drooping.

The training and development of the potato from a wild Chilian, swamp-loving root into a vegetable that has practically become a necessity of life, in the British Isles at least, is an almost inexhaustible theme. I have, however, only space to touch upon it here, and must content myself with remarking that the same methods of procedure which have been so successful with regard to the potato have given us our juicy apples from the once despised crab of the hedgerows (*Pyrus Malus*), our luscious pears from a close relative (*Pyrus baccata*), and our plums from ancestors whose fruits were but as sloes in comparison. In every case, as far as man is concerned, the "new" is much better than the "old."

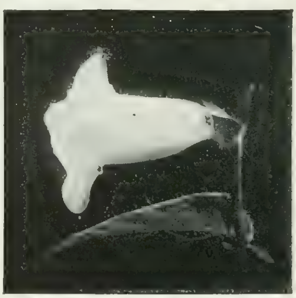


Photo: Sutton & Sons, Reading.
FIG. 8.—THE GROWTH OF THE GLOXINIA.
The flower begins to lift its head and increase in size.

* The disc florets may be easily seen in the yellow "eye" of the common daisy. The ray florets are the white strap-shaped ones at the outside of the flower head.

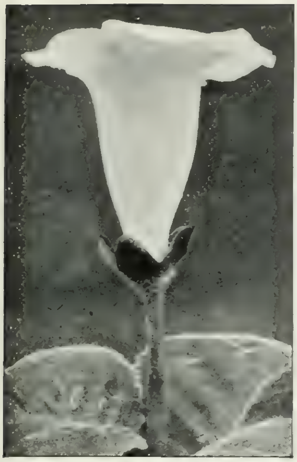


Photo: Messrs. Sutton & Sons, Reading.

FIG. 9.—THE GROWTH OF THE GLOXINIA.

The modern flower, boldly erect, and several times bigger than the original.

A similar tale might be told of the highly bred vegetables that stock our kitchen gardens, and we may well take a special look at the carrot, seeing that it instances development upon a line that we have not yet looked at. Surely there could never have been a more unpromising specimen than the weedy wild carrot of our hedgerows. Given to habits of prodigality, it was content to flourish for one season only; in other words, its duration of growth was *annual.* Man came: he liked not the old roots—he wanted bigger and sweeter ones; but in order to get them he had to train his charge to be less prodigal, to take a longer season of growth, and store up more food in its sturdy root. Now we find that the modern carrot is *biennial* in duration; but —alas! that it must be said—old habits will out, and the biennial habit is not, after all, very deeply ingrained as yet. Occasionally the plant breaks through the trammels, and reverts to the weedy ways of its ancestors.

It has been declared over and over again that the plant breeder is artificial in his methods. To some extent this is true; to a greater extent it is not true. In many respects Nature has pointed out the methods which are likely to prove most successful. Some of these we have already noted. Let us look at some others. Nature is striving to reconcile organisms with environments; the cultivator tries to make environments suit his plants, but *reconciliation of environment and organism* is the desire of both.

Further, we notice that the plant breeder, after selecting the forms he finds desirable, destroys the others, and thus *gets rid of the link plants.* It is more than possible—it is exceedingly probable—that Nature has done the same. One result of this probable destruction of intermediate forms is that *species* of plants are frequently regarded as distinct from each other because we are not able to compare them with their ancestors or

FIG. 10.—THE GROWTH OF THE GLOXINIA.

The "new" plant. Compare with the "old" in Fig 6.

connecting links which, it is almost certain, must at one time have existed. Plants which have been in cultivation for many years cannot sometimes be compared with their ancestors, for the simple reason that the latter are no longer in existence. Take the cultivated wheat, for instance. We know what this is, but what was the ancestral wheat like? We can only guess, for it has no longer an existence. Away back in those shadowy years of the Lake-dwellers and the Kitchen-middeners the value of wheat was known, and the plant was cultivated. But the old wheat has gone entirely; it has been improved off the face of the earth. In many of the other instances of familiar garden plants, some of which are illustrated in this article, both old and new exist side by side, and by comparing the one with the other we are able to appreciate the amount of progress that has been made.

We have noticed already how important a part continued interbreeding plays in the process by which new plants are obtained, and in this respect, at least, the plant-

Photo: Messrs. Sutton & Sons, Reading.

FIG. 11.—THE "OLD" STYLE OF CHINA ASTER (*CALLISTEPHUS HORTENSIS*).

Compare with Fig. 12.

Photo: Messrs. Sutton & Sons, Reading.

FIG. 12.—THE "NEW" CHINA ASTER.

Compare with Fig. 11.

raiser has something to answer for, seeing that in this case his methods appear to be violations of some of Nature's laws. We do not need to study plants very closely to find out that, as a rule, Nature prefers cross-fertilisation for her flowers, where possible. There are not lacking notable exceptions of flowers that are fertilised by their own pollen, but still the rule remains good. The numerous devices by which *self*-fertilisation is prevented and *cross*-fertilisation effected constitute one of the most interesting chapters of natural history. It is far too important to be dismissed in a few words, and, although space will not permit of more than a passing reference at this time, the subject will be taken up again in a future paper. It may be stated now, however, that self-fertilisation is not looked upon favourably by Nature. Further, that when the plant-breeder persists in consistently inbreeding he—or rather the plant he is dealing with—has a penalty to pay—viz. a weakened

constitution and a corresponding liability to the attacks of those hordes of fungoid pests which only appear to be waiting their opportunity to strike. The opportunity comes when the vitality of the plant is so lowered that resistance to attack is weak and ineffective. We all know that history has many examples to offer of once hardy peoples, whom no amount of oppression could subdue, being enervated and destroyed by too luxurious surroundings. Witness the decay and death of the great Macedonian and Roman empires. As in the world of man, so in the world of plants. Our floral pets, especially those which stand at the apex, as it were, of a long line of closely interbred generations, are, with few exceptions, incapable of fighting the battle of life for themselves. Luxurious surroundings, the experience of being shielded from adverse circumstances, has robbed them of much of their power to resist should these adverse circumstances befall them. The highly bred carrot or chrysanthemum would stand but a sorry chance if left to fend for itself. The carrot would survive perhaps, but as a degraded representative of a modern root, for its offspring would speedily revert to a type of plant closely approaching the original—weedy and irresponsible, but hardy as of yore. The chrysanthemum, poor child of an Eastern sun, would almost certainly fare much worse. It might make a desperate attempt at *atavism*, or reversion to a previous type, but even that could not make up for the fact that it is not of British birth.

FIG. 13.—CARROTS NEW AND OLD.

The weedy-looking root on the right belongs to the wild carrot ("Daucus Carota"), a common British wilding.

Little has been said about the development of colour, and the subject is far too big to be lightly summed up. The florist finds, however, that colour change is easy

to get, and, as a rule, easy to "fix" in the plant. What may be called the two original colours, after green, with which Nature has been working, and after her the florist, are yellow and rosy red. Blue and shades of blue are a much later development; indeed, the maker of new flowers has been trying for years to get blue amongst his roses, carnations, and chrysanthemums—to mention only a few. But both blue rose and blue chrysanthemum seem to be as far off as ever, in spite of newspaper reports. We must wait a little longer; Dame Nature will not be hurried beyond a certain point.

The so-called green rose, which comes up for discussion now and again, like the sea-serpent, is really an unmade flower—a reversion to a former state of affairs before that marvellous colour scheme of our earth had been developed, before man had planted his garden, probably long before man had appeared upon the scene at all.

The plant breeder, then, can do much. He can alter the colour of a flower and increase its size to an astonishing degree; but the moment he removes the artificial environment which has helped to make these things possible, his highly bred pets dwindle and disappear, as Imperial Rome crumbled beneath the strenuous approach of Alaric and his Goths.

FIG. 14.—*PYRUS MALUS*, THE CRAB APPLE.
This is the parent of the many fine varieties of apples which our gardens produce.

THE WIZARD ELECTRICITY.—II.

HOW ELECTRICITY IS MEASURED.

By FRANK C. WEEDON.

IN considering "a working dynamo" we found that if two wires are joined, one to each of the dynamo terminals, and the free ends connected with an electric lamp, so as to make a

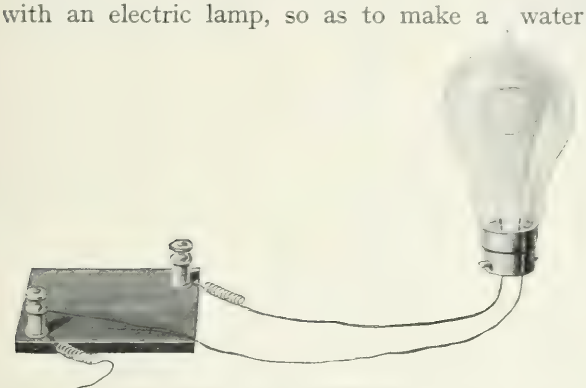


FIG. 1.—ILLUSTRATING THE "FLOWING" OF AN ELECTRIC CURRENT.

An electric glow lamp connected with the terminals from a dynamo.

complete conducting circuit from one terminal to the other, then the lamp will glow (Fig. 1). This was considered as sufficient indication that an *electric current* was *flowing* from one terminal to the other. Nothing was offered in explanation of these terms, "current" and "flow," when used in connection with electricity, because a full explanation of such terms is a matter of great difficulty and out of place in an introductory article.

Many of the terms used in electrical science were introduced years ago, when electricity was thought to be a fluid which moved along the conducting wires, and they are still employed, not because they actually describe what takes place, but because they enable us to figuratively discuss in simple language phenomena which are in reality highly complex.

Consider the experiment represented in Fig. 2. There are two glass tumblers containing water, in *A* hot and in *B* cold. A piece of stout copper wire is bent so as to dip into the water in both glasses. The thermometer will speedily show that heat travels along the wire from the hot water to the cold. The copper wire is said to be a *conductor* of heat, and the indication of the experiment is that *heat will flow along a conductor from a higher to a lower temperature.*

Of course, the heat is not a substance which thus flows along the conductor, but it is easier to speak of the experiment in these terms than to attempt a description of the transference of a condition of molecular vibration from the hot to the cold water along the conducting wire. In describing the experiment in this manner, we are, in fact, referring to another experiment, which is usefully analogous :—

Two vessels, *A* and *B* (Fig. 3), contain

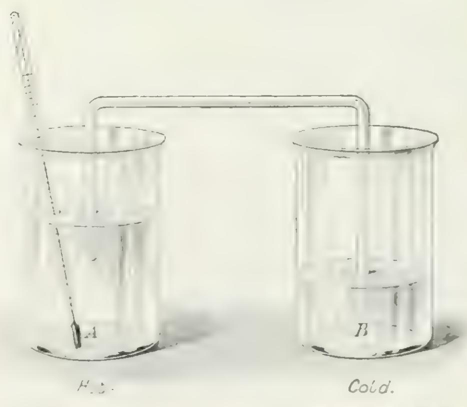


FIG. 2.—SHOWING THE PASSAGE OF "HEAT" FROM HOT WATER TO COLD ALONG A "CONDUCTOR" OF COPPER WIRE.

water, and are in communication with each other by means of a pipe. If the level of the water is higher in *B* than in *A*, water will flow into *A* until the level

in both vessels is the same. These two simple experiments resemble each other in those points which are of importance

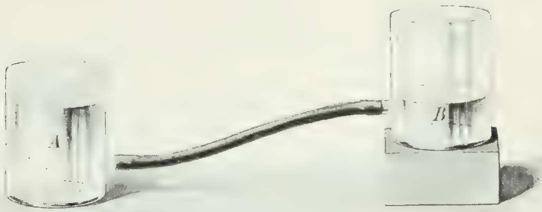


FIG. 3.—WATER FLOWING FROM A HIGHER TO A LOWER LEVEL.
Note that there is a difference in "level" and a "conductor."

in electrical analogy. There is in each case a current when—

(*a*) There is a difference of level.

(*b*) There is a conductor.

If the level in *B* is much above that in *A*, the flow will be greater than if the difference is small, and, other things remaining unaffected, the larger the pipe the faster the flow.

Turning now to electricity, imagine two brass balls, *A* and *B* (Fig. 4), hanging by threads of dry silk. We can join *A* to the knob of an electrical machine and so put electricity into it. This we can satisfy ourselves about by presenting a finger towards *A*. If we get a tiny spark, we shall be certain that joining *A* to the machine charges it electrically. If we test *B*, and find that it is in its usual condition, we can confidently state that the two balls are in different electrical conditions—one higher than the other electrically. If the two balls are allowed to touch, or if a metal wire is made to connect them, we find that they are both altered to the same electrical level. We think of the water, and say that electricity has flowed from the higher to the lower level. One has lost electricity and the other has gained, until both are at the same level. The constant use of the word "level" in this argument suggests that for the electrical experiment we want a suitable word. That word is *potential*.

Difference of level, then, causes a flow of liquid; difference of temperature results in a flow of heat; and difference of *potential* causes a flow of electricity—that is, it results in an electric current. If the analogy of the water pipe is borne in mind, it will be expected that the rate of flow will be great if the difference of "potential" is great. The width of the water pipe affects the flow of liquid, and the size of the electrical counterpart—the wire—similarly affects the current of electricity. The opposition offered to the electrical current is called the *resistance*. We thus arrive at the following conclusion—*an electrical current is proportional to the potential difference producing it, and it varies inversely with resistance to its path or circuit.*

This great law of electrical flow is called, after Dr. Ohm, its discoverer, "Ohm's law." It may be expressed thus :—

$$\text{Current} = \frac{\text{Difference of potential}}{\text{resistance.}}$$

We may at this stage, accordingly, say

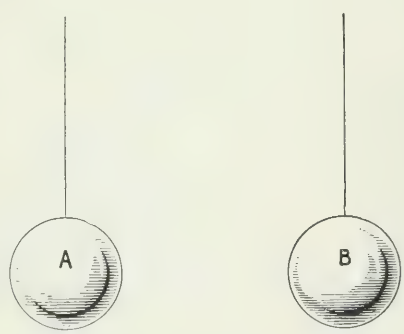


FIG. 4.—TWO BRASS BALLS HANGING BY SILKEN THREADS.

By charging one ball electrically and then connecting the two balls by a copper wire a "flow" of electricity may be demonstrated.

that electrical measurement is of three kinds :—

(1) Measurement of current.

(2) Measurement of resistance.

(3) Measurement of potential difference.

The flow of an electric current along a wire makes that wire hot. At the same time it produces a magnetic field, the lines of force of which are concentric circles with the wire as centre; so that if the wire is wound into a spiral or coil, the coil will be an electro-magnet as long as the current is passing. If the circuit is formed in part by a solution of a metallic salt, the current gets across the liquid, and in so doing "plates" the metal of the salt on the end of the wire by which it leaves the solution.

These three results—the heating effect, the magnetic effect, and the chemical effect—may be illustrated by the experiment pictured in Fig. 5.

Two Bunsen cells are joined "in series"—*i.e.* one after the other—with (*A*) a coil of thin iron wire, (*B*) a coil of cotton-covered copper wire, and (*C*) a voltameter. This last is a pot containing a solution of a metallic salt—copper sulphate preferably. Dipping into the solution are two plates of thin sheet copper, one joined to each of the wires, as shown.

When the current passes, the coil in *A* becomes heated and raises the temperature of the water surrounding it, the needle in the coil *B* is deflected, and copper is deposited on the plate by which the current leaves the electrolytic cell *C*. If we alter the current, the effects in *A*, *B*, and *C* all alter simultaneously, and we find that each effect varies with the current, and may therefore be employed in measurement.

We owe to Faraday the discovery of the laws of the chemical effect of a current in solutions. The process he named *electrolysis*, and those substances which are decomposed he termed *electrolytes*. The terminations of the wires in the substance are *electrodes*, that by which the current enters is called the *anode*, and the other electrode is called the *kathode*. Faraday found that electrolytic effect is not subject to chance, but is governed by definite laws. The quantity of metal, for instance, plated in an electroplating bath depends on the current and on the time the current is flowing. The complete statement is:—

Weight deposited = current (in ampères) × time (in seconds) × the electro-chemical equivalent.

The electro-chemical equivalent is a

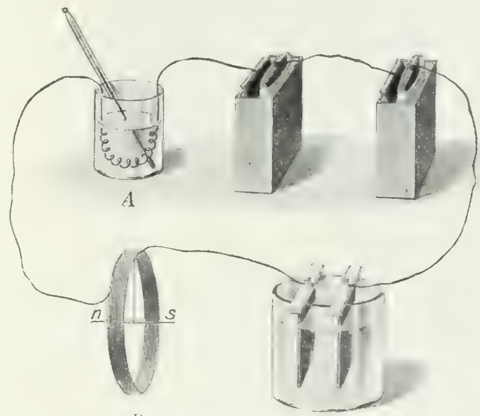


FIG. 5.—SHOWING HOW HEATING, MAGNETIC, AND CHEMICAL EFFECTS ATTEND A FLOW OF ELECTRICITY.

A. A coil of thin copper wire in a vessel containing water.
B. A coil of cotton-covered copper wire.
C. A pot containing copper sulphate in solution.
n, s. The poles of a magnet suspended in coil B.

number which is peculiar to each metal, and can be found by experiment.

The *ampère* is the unit in which current electricity is generally measured, and is based on Faraday's laws. It is defined as "*the electrical current of unvarying strength which, when passed through a neutral solution of nitrate of silver containing* 15 *parts by weight of the salt to* 85 *of water, using a silver anode and a platinum kathode, deposits silver at the rate of* 0·001118 *of a gramme per second.*"

It follows, from what has been said, that if a voltameter is included in an electric circuit, we can, by observing the weight of metal deposited and the time taken, calculate the strength of the current—assuming it to be uniform. Voltameters, are, however, not often used

in this way. A convenient form of copper sulphate voltameter is shown in Fig. 6. The solution is placed in the light bowl *B*, made of copper. This stands on a piece of clean copper provided with a screw terminal *D*. A cylinder of pure copper *C* dips into the solution, and the current passes from *A* through *C* to *B*, carrying the copper, which is plated on the bowl. After the current has been flowing for a considerable time, the solution is poured out, and the bowl carefully washed and dried. The difference in weight of the bowl before and after the experiment gives the amount of copper deposited.

Turning now to the measurement of the current by the magnetic effect, we have seen that if a current is passing along a wire wound into a coil, the lines of force of the magnetic field at the centre of the coil are parallel to the axis of the coil —that is, the magnetic lines run side by side with the spindle on which the coil would turn if it were a wheel. Imagine a coil placed so that its axis points E

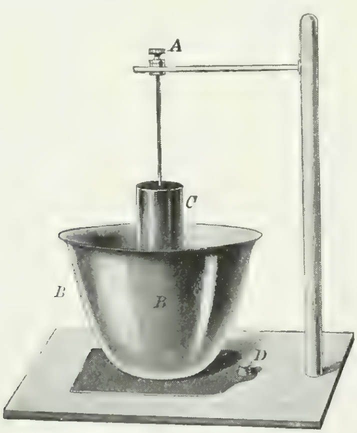


FIG. 6.—A COPPER SULPHATE VOLTAMETER.

B, a copper bowl; C, a cylinder of copper; D and A, screw terminals.

and W, and a short magnet pivoted or suspended at the centre of the coil. When no current passes round the coil the magnet will point N. and S.—that is, at right angles to the axis of the coil. When the current passes there will be at the centre of the coil two magnetic fields, with their lines of force mutually at right angles.

The magnet is urged simultaneously

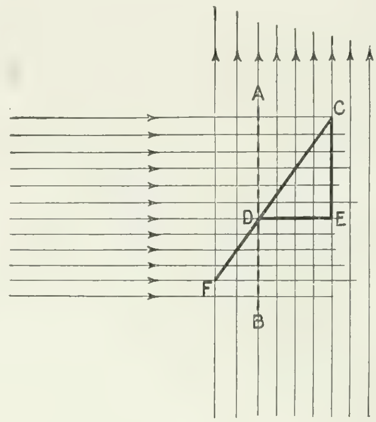


FIG. 7.—LINES OF FORCE OF TWO MAGNETIC FIELDS AT RIGHT ANGLES TO EACH OTHER.

F D C, a magnetic needle which comes to rest along the line representing the "resultant" of these two forces.

to come to rest with its axis in both of these directions, and in accordance with a well-known law it finally rests along the *resultant* of the two forces— viz. the force due to the field of the earth, and that due to the current flowing round the coil.

The ruled lines in Fig. 7 represent the lines of force of the two magnetic fields, and F D C the direction in which the magnet comes to rest. If we draw lines parallel to the two magnetic forces and their resultant, making the triangle D E C, it can easily be proved that:—

$$\frac{\text{The length of DE}}{\text{The length of EC}} = \frac{\text{The intensity of the field due to coil}}{\text{The intensity of the earth's field.}}$$

Now the magnetic force at the centre of the coil varies with the current producing it, so that if we pass a current through such a coil properly adjusted, and observe the angle of deflection of

the small magnet, and do the same when a second current is passed, then

$$\frac{\text{The strength of the first current}}{\text{The strength of the second current}} = \frac{\text{The tangent of the first deflection}}{\text{The tangent of the second deflection}}$$

Coils suitably mounted for measurements of this nature are called *tangent galvanometers*.

Measurements with tangent galvanometers obviously require calculations on every separate occasion, and this is a drawback. We can, however, join a voltameter "in series" with a tangent galvanometer, and from the weight of metal deposited find the current producing a certain deflection. A number of such observations can be made with different strengths of current, and from the facts collected a table can be made which converts the galvanometer into an instrument showing by its needle deflection the actual strength of a current passing through it. Such an instrument is called an *ampère-meter*, often contracted

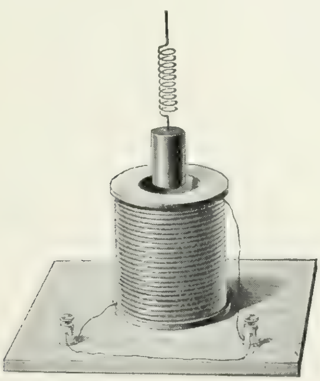


FIG. 8.—AN AMMETER OF THE MAGNETIC TYPE.

into *ammeter*. "Ammeters" are extensively used in commercial electrical work There are various types, but they are all *direct-reading* instruments—that is, the movement of the pointer at once shows, without any calculation, the strength of the current passing.

The principles of ammeter construction will readily be understood by the reader who realises the magnetic condition of a coil carrying a current. The magnetic flux may be directed so as to attract a piece of soft iron attached to a pivoted

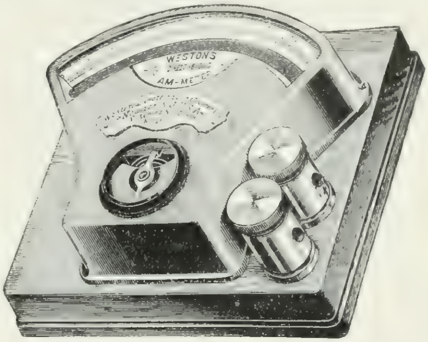


FIG. 9.—THE WESTON AMMETER.
This is light, portable and handy.

rod. The movement of the iron can be opposed by the force of a spring, and indicated by a pointer attached to the pivoted rod.

Or the current may be passed through a coil made to rotate between the poles of a permanent magnet. The rotation can be checked by a spring, as above. Ammeters of this type are largely used on account of their portability. The Weston instruments are of this class, and are much esteemed (Fig. 9).

In another type of ammeter the force which balances the movement of the piece of iron or moving coil is not a spring, but gravity. Gravity ammeters require careful fixing, and, although not portable, they are much valued on account of their reliability.

In another current-measuring instrument the magnetic force is calculated somewhat on the principle of the steel-yard. In this ammeter—the "Kelvin balance"—the current to be measured passes through coils one at each end of the balance beam. The current also passes through fixed coils above and below the moving coils, so arranged that there is a downward tendency of the moving coil on one side and an upward tendency

of the other. These forces are balanced by a weight which slides along the beam (Fig. 10).

It is a well known fact that if a wire is made hotter, it becomes longer, and the increase in length is proportional to the rise in temperature. If the rise in temperature is caused by a current, and if the heated wire is screened from draughts, it speedily elongates by an amount which is proportional to the current. These facts are made use of in current measuring instruments called *hot wire ammeters*. Fig. 11 shows the wire, which by its expansion sags, and causes the pointer to move. These hot wire instruments are very reliable, and portable.

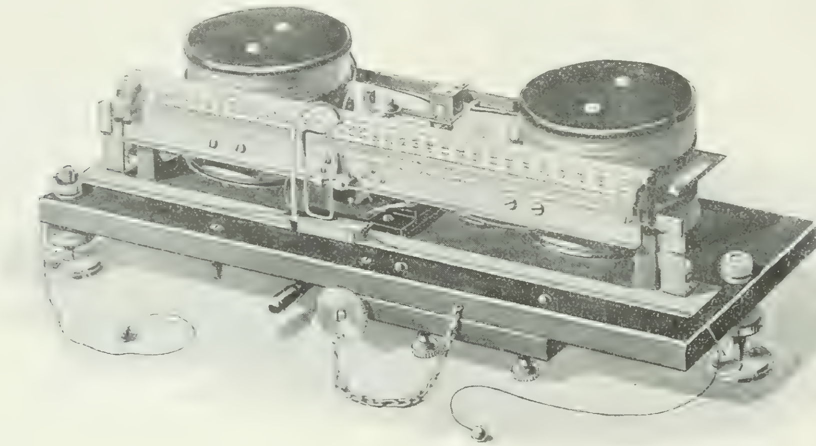


FIG. 10.—THE KELVIN BALANCE.

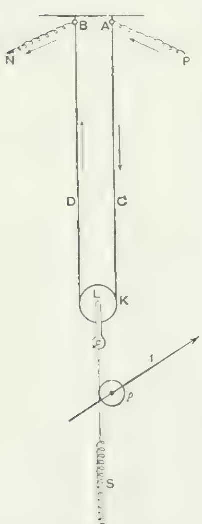


FIG. 11.—A HOT WIRE AMMETER.

It is occasionally useful to have a record of the current taken continuously during an interval of time. Recording instruments are used for this purpose, and the illustration (Fig. 12) sufficiently illustrates the working.

We have already seen that the production of a current depends on the difference of potential, or, as it is often termed, "electrical pressure." Conversely, if a current is flowing along a conductor, its two ends must be at different potentials, and any point on the conductor must be at a higher potential than another point further along the conductor, measuring in the direction in which the current is flowing (*see* Fig. 13). Thus, if *A B* is a wire carrying a current, as shown by the arrows, *A* is at a higher potential than *B*, and *C* is higher than *D*. That is, there is a fall of potential along the conductor, and if this is a uniform wire the potential drop is proportional to distances measured along the wire. This gives us a means of comparing potentials.

A uniform wire *A B* (Fig. 14) is stretched for convenience over a scale. A battery giving a steady current along this wire is joined to *A B*. Then there will be difference of potentials between any two points *m* and *h*. If the two ends of a conducting branch *m C G h* are made to touch, as shown, the difference of potentials will establish a current along this branch, as shown by the arrows. If a cell is included in this branch so as to tend to send a current opposed to that caused by the main current, the resulting current

FIG. 12.—A RECORDING INSTRUMENT.

indicated by the galvanometer G will be caused by the difference between the two opposing electrical pressures. The distance $m h$ can easily be adjusted so that the two opposing electrical pressures in the branch are exactly equal, and no current flows. Then the difference of potential of the terminals of the cell equals the difference of potentials at the points $m h$ on the main wire, and *this difference of potential depends upon the length of wire between m and h.* If the cell C is now replaced by a cell c_1, and the balance is found at $p h$, then the difference of potential at the terminals (or voltage) of the cells is easily compared. For

$$\frac{\text{Pressure of } C}{\text{Pressure of } c_1} = \frac{\text{Length of wire } m h}{\text{Length of wire } p h.}$$

Instruments made on this principle are called *potentiometers.* The unit of electrical pressure commonly used is the *volt,* which is *the difference of potential which will maintain a current of one ampère through a resistance of one ohm.* Instruments to measure *volts* are called *voltmeters.*

Any galvanometer or ammeter may be used as a voltmeter if the coil offers sufficient resistance to the flow of the current. For, if the resistance of the coil is great, the current flowing through it will be small, but what little there is will be exactly proportional to the difference of potential between its terminals. Hence the account of ammeters applies to voltmeters, and we have moving coil voltmeters, gravity control voltmeters, electro-magnetic voltmeters, and hot wire voltmeters.

FIG. 13.—ILLUSTRATING A "FALL" OF "POTENTIAL" ALONG A CONDUCTOR.

All these voltmeters, however, take away some current from the main circuit, and when this is not desired an *electrostatic voltmeter* may be used (Fig. 15). The principle of this instrument may in outline be stated thus. There are two

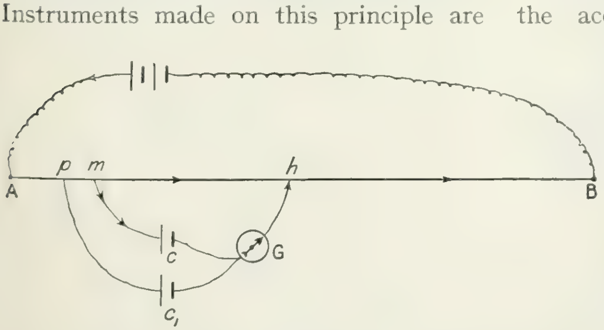


FIG. 14.—ILLUSTRATING THE WORKING OF A "POTENTIOMETER"

m h, p h, are connecting branches.
A, B. The course taken by the main current.
c, c_1. Cells. G. Galvanometer

sets of metal plates, one set fixed and the other movable. If these two sets are respectively at a different potential, there is set up an attractive force between them which varies with the square of the difference of potential. This force urges the movable set of plates towards the fixed ones, and if this force is balanced by gravity, or a spring, a needle can be fastened to the movable set so as to

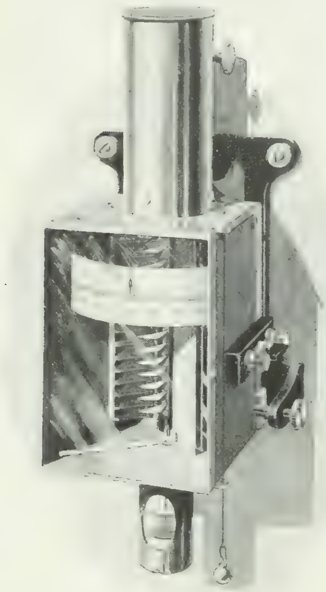


FIG. 15.—AN ELECTROSTATIC VOLTMETER.

indicate on a scale the potential difference between the sets of plates.

We have already compared an electric current to a stream of water. If the diagram (Fig. 16) represents a river which divides at *a* and unites again at *c*, from *a* to *c* there is the same fall towards the sea-level whether we go by the upper or lower branch. Consequently, for any point *b* there must be a point *d* at the same level, so that if a trench were cut no stream would flow from *b* to *d* or *d* to *b*. Apply this to the case of an electric current branching at *a* and uniting at *c*. If we find a point *d*, so that no current flows along *b d*, then *b* and *d* are at the same potentials.

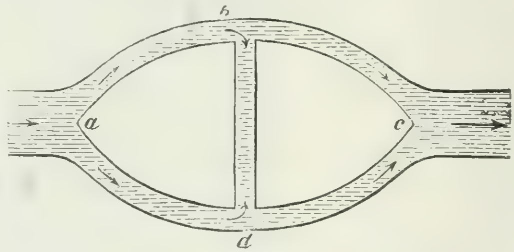


FIG. 16.—AN ELECTRIC CURRENT COMPARED TO A STREAM OF WATER.

The arrows show the direction of the current, which divides at a, to reunite at c.

When this is so, it can be shown that

$$\frac{\text{The resistance along } a\,b}{\text{The resistance along } a\,d} = \frac{\text{The resistance along } b\,c}{\text{The resistance along } d\,c}.$$

This is the principle of an instrument for comparing resistances, called "Wheatstone's bridge." Fig. 17 shows a simple form of this apparatus. The resistance of the wires *a b* and *b c* are equal, and when the resistances *W* and *R* are so

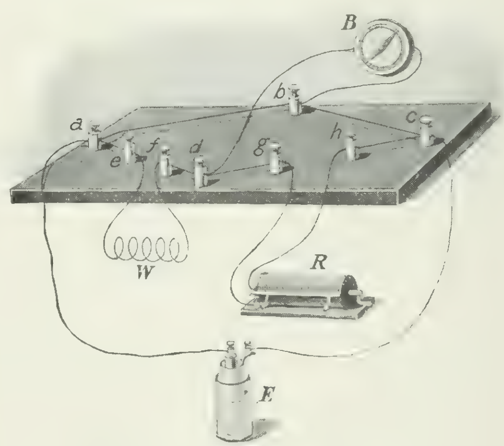


FIG. 17.—WHEATSTONE'S BRIDGE.

a b and b c are conductors of equal resistance.
W and R are conductors to be compared.
B is a sensitive galvanometer.
E is a cell or battery.
d, e, f, g, h, conductors.

adjusted that no deflection of a sensitive galvanometer is observed, then, as above,

$$\frac{a\,b}{b\,c} = \frac{W}{R},$$

and since $a\,b = b\,c$, it follows that $W = R$. If $a\,b\,c$ is stretched along a scale, we can by the above method compare resistances W and R when they are not quite equal, by comparing the length

$$\frac{a\,b}{b\,c}$$

where the balancing point is obtained.

If we wish to measure resistances, we shall use for R a standard resistance.

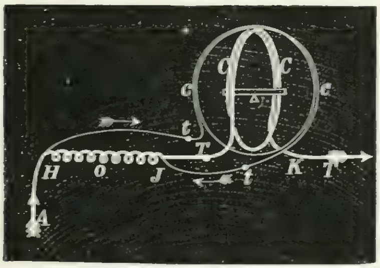


FIG. 18.—DIAGRAM OF AN OHMMETER.

H J represents the resistance to be tested.
c c is the voltmeter coil.
C C is the ammeter coil.

The chief unit of resistance, *the ohm*, is *the resistance offered to an unvarying electric current by a column of pure mercury of constant cross section at* 0° *C.*, 106·3 *centimetres long and weighing* 14.4521 *grammes.*

Carefully constructed coils of wire having standard resistances are used in ordinary work. They are wound *double*, as in the illustration (Fig. 19), so as to avoid the production of electro-magnets while the current is passing. For convenience a number of these resistances are fastened in series to stout pieces of brass attached to the lid of a box, inside which the coil is suspended. The brass plug thrust into the hole carries the current along the brass, but its removal sends the current through the coil. Fig. 20 shows a resistance box.

There are special methods for measuring very high and low resistances, which cannot be described here. In measuring

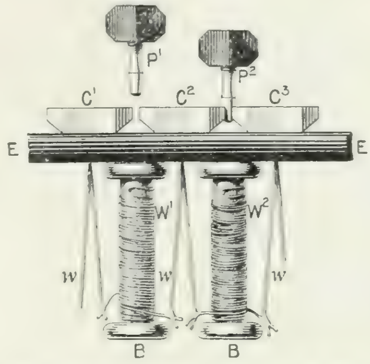


FIG. 19.—RESISTANCE COIL AND PLUG.

The wires are doubled before they are wound on the bobbins B B.

the insulation resistance of the electric light wiring of a house, an *ohmmeter* is used. The principle of this instrument may be understood by reference to Fig. 18.

There are two coils, the *current coil* C C and the *pressure coil c c*, arranged at right angles to each other. There is a magnetic needle which is influenced by the current in both of these coils. The coil C C is in series with the circuit, while the ends of the coil *c c* are shunted across H J, the resistance to be measured. The

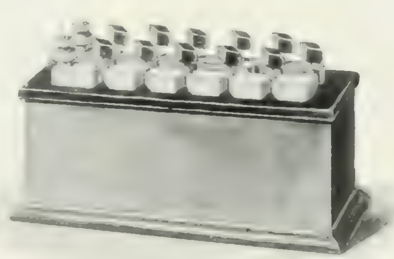


FIG. 20.—RESISTANCE BOX.

resistance of the current coil being low, and that of the pressure coil being high, it follows that the forces deflecting the needle will be proportional to the difference

of potential between the points H and J, and to the current flowing along H J. Accordingly, the angle of deflection will be proportional to the ratio—

$$\frac{\text{Potential difference H to J}}{\text{Current flowing in H J},}$$

that is, by Ohm's law, the deflections will indicate the resistance of H J.

Summarising, we say that the number of *ampères** of current flowing in an electric circuit varies (1) *directly* with the number of *volts†* of electric pressure producing the current, and (2) *inversely* with the number of *ohms‡* of resistance opposing it. That is, Ohm's law, $C = \frac{E}{R}$.

In addition to the instruments described in this article, there are others which are used in the commercial applications of electricity. Different types of electric meters will be dealt with in a subsequent article on "Electric Lighting."

* An ampère is the unit by which quantity is measured: it is the electrical current which, when passed through a solution of nitrate of silver containing 15 parts by weight of the salt to 85 of water, using a silver anode and a platinum kathode, deposits silver at the rate of 0·001118 of a gramme per second.

† A volt is the unit by which the strength of the current is measured: it is the difference of potential which will maintain a current of one ampère in a conductor the resistance of which is one ohm.

‡ An ohm is the resistance offered to an unvarying electric current by a column of pure mercury of constant cross section, at 0° C., 106·3 centimetres long, and weighing 14·4521 grammes.

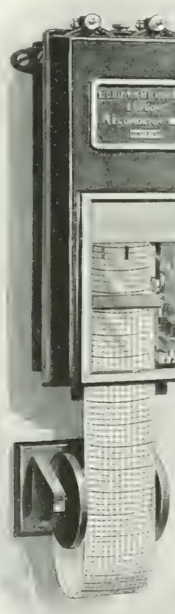


FIG. 21.—RECORDING AMMETER.

HOW AND WHY A STONE FALLS.

THE time-honoured story of Sir Isaac Newton having had his attention directed to the laws of gravitation by the fall of an apple from a tree may or may not be true. The legend, however, points to a fact full of scientific meaning, that the grandest secrets of nature may be ascertained from a careful study of the most ordinary and everyday occurrences; and in this article an endeavour will be made to show that from "the fall of a stone" those great laws the discovery of which have made Newton's name immortal may be learned.

We are all aware that if we throw a stone straight up into the air its speed upwards gradually grows less and less, until it stops for an instant, then returns to the earth again with ever-increasing velocity until it strikes the ground. Let us suppose that just at the instant when the stone is at its greatest height, and when it is stationary, the earth is suddenly removed entirely away. Let us inquire what would be the behaviour of the stone. Most people would at once conclude that, of course, it would fall downwards and continue its course, there being nothing to arrest its progress. We all have such an instinctive notion that bodies ought to fall downwards when there is nothing to support them that such would seem the natural conclusion. A little consideration, however, will show us that this opinion is not so well founded as at first sight appears.

The earth being a globe or ball-like body, revolving on its axis once in twenty-four hours, it follows that, except in very high latitudes, our directions are completely reversed every twelve hours, so that what is up in the one case is down in the other. Suppose Fig. 1 to represent the earth revolving from left to right in the direction of the bent arrows. Now, an observer standing at A at twelve o'clock in the day would consider upwards to be in the direction of the top of the page and downwards in the direction of the bottom. At twelve o'clock at night he would be standing at C, and these directions would be completely reversed, so that upwards would now be towards the bottom and downwards towards the top of the page. A stone, therefore, thrown up by this observer at twelve o'clock noon would fall in an exactly

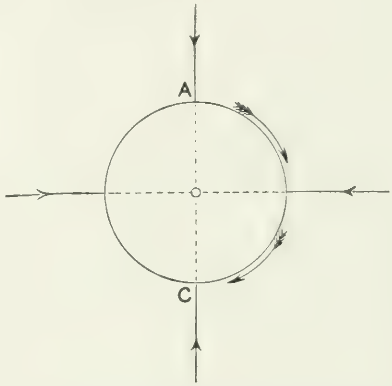


FIG. 1.—ILLUSTRATING THE FALL OF A STONE RELATIVE TO THE EARTH'S CENTRE.

opposite direction to one thrown up at midnight. Further, at intermediate times, say at six p.m. and six a.m., the directions would be at right angles to those at twelve noon and twelve midnight; these directions are shown by the straight arrows in the figure. We thus see that our notion of falling downwards is not correct in the ordinary sense in which we use it. Moreover, if we look at the directions of the arrows at the various times, we see that if these directions were prolonged they would meet at a point in the centre of the figure of the earth. We are therefore justified in concluding that when a stone falls it is drawn or attracted towards the centre of the earth. If this conclusion be correct, then it is

evident that the motion of the stone is really due to the presence of the earth, and if, as we have supposed, the latter were suddenly withdrawn when the stone was for the instant without motion, the stone would just remain in exactly the same position as it was—there would be neither upward nor downward motion. The correctness of this idea will be strengthened if we consider the stars and planets, which are really in the position of the stone we are considering, unsupported in space; and, although they move in a manner afterwards to be described, they do not fall out of their places as we have imagined the stone might do. From these considerations we arrive at the law that a stone—or, indeed, any body—*will remain exactly in the place where it is put, provided no force from without acts upon it.*

Advancing a step further, let us next consider what would be the behaviour of the stone if the earth were suddenly removed, not at the instant when it was motionless, but when it was moving with some velocity towards the earth. Here, again, we might be tempted to conclude that when the earth, the cause of the motion, was removed, the motion would cease and the stone would come to a standstill; but, in this case also, further consideration would change our ideas. We know from experience that when any body is moving, such as a cricket or cannon ball, we require to exercise considerable force of resistance to stop it. We observe also that the velocity of the falling stone gradually increases as it approaches the earth. This shows us that the attraction of the earth is gradually accumulating force in the stone, so to speak; the effect produced during the first second remaining in the stone, while the effect during the second second is added to it, and it is only the resistance offered by the solid ground that prevents the stone from continuing its onward course. It is evident, therefore, that, in the case supposed, if the earth were suddenly removed the stone would continue its onward course with unabated speed, not, however, increasing the speed at which it happened to be moving when the earth was withdrawn. We thus attain to a second law: that *any moving body will continue that movement without either increase or diminution provided no force from without acts upon it.*

From these two laws we arrive at a knowledge of the fact that matter of any kind is quite inert, and has no inherent power to change its state. If it is put in any position, there it remains; if moved in any direction or at any speed, in that direction and at that speed it continues to move provided that nothing from without modifies that direction or that speed. It adds nothing, it takes away nothing, from any force communicated to it, but simply acts as a carrier, receiving and delivering up with rigid exactness whatever may be committed to its charge. This inertness of matter is at the foundation of all physical philosophy and the science of mechanics, and it is of great importance that we should thoroughly grasp and understand it.

Turning our attention once more to the falling stone, let us consider more minutely its behaviour on approaching the earth; let us note its velocity during a fall of one, two, or three seconds. It has been very accurately determined that a stone under the action of the earth's attraction for one second will pass through a space of about 16 feet, and will, at the end of the second, be moving at the rate of 32 feet per second. At the end of two seconds it will have passed through a space of 64 feet, and its velocity will be 64 feet per second. At the end of three seconds the space passed through will be 144 feet and the velocity 96 feet per second, and so on. Tabulating these results we at once become aware of an exceedingly regular law, viz. that the velocity increases 32 feet per second every second, while the space passed through increases as the square of the number of seconds.

No. of Seconds.	Space Fallen Through.	Velocity Acquired.
One	16 ft.	32 ft. per sec.
Two	$16 \times 2 \times 2 = 64$ ft.	$32 \times 2 = 64$,,
Three	$16 \times 3 \times 3 = 144$ ft.	$32 \times 3 = 96$,,

During two seconds the body does not fall through twice 16 feet, but through four times 16 feet, and four is the square of two, and so on, with three, four, or any number of seconds. Now, this result entirely confirms what we have said about the inertness of matter. Consider the space fallen through in two seconds, for instance. In the first second it has passed through 16 feet, and has acquired a velocity of 32 feet per second. If it were to proceed at this velocity it would pass through 32 feet in the next second, but the attraction of the earth continuing causes it to pass through another 16 feet; this, added to the 32 feet, makes altogether 48 feet passed through in the second second, and this, added to the 16 feet first passed through, makes 64 feet for the two seconds, that is, the distance mentioned in the above table. And so, if we calculate for any number of seconds; the stone falls to earth from rest with an acceleration of velocity of 32 feet per second per second. That is, for every second of its fall its *rate* of falling increases by a speed of 32 feet per second. It will be noted, then, that the *acceleration* is regular. The falling stone obeys exactly the force acting upon it, neither adding to nor taking from it.

To find the space fallen through during any second of the fall the mean speed per second should be calculated. Thus, at the beginning of the seventh second of its fall the stone will have a velocity of 192 feet per second; at the end of that second the velocity will be $192+32=224$ feet per second.

The mean velocity for the seventh second will therefore be $\frac{416}{2} = 208$ feet per second. What, then, is the exact meaning of the statement that a stone has a velocity of 208 feet per second? It means that if it continues to move at the same rate for a second it will have passed through 208 feet. And we have found that it will do this unless some force from outside itself impinges upon it, and thus modifies movement or direction or both.

The force of gravity, expressed in terms of the acceleration which it produces in a falling body, varies slightly in different parts of the earth's surface. Thus, at the equator it is 32·091 feet per second per second, at Aberdeen it is 32·206 feet per second per second. In fact, intensity of gravity increases slightly as we pass from the equator to the poles. There is also a slight variation according to the altitude. For convenience of calculation fractions may be ignored, and the value of g, as it

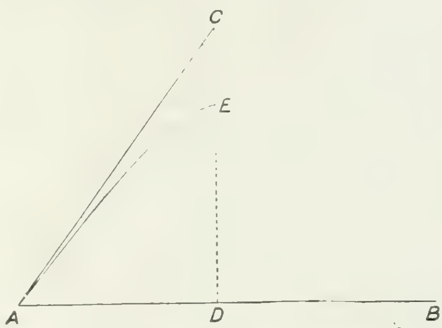


FIG. 2.—A STONE THROWN UPWARDS AT AN ANGLE DESCRIBES A PARABOLA.

is called by mathematicians, may be regarded as being 32 feet per second per second.

We have thus followed the movement of the stone in falling towards the earth, and traced the laws of its motion. If we now study the converse problem, viz. the rising of the stone from the earth, we shall reach the same conclusions; for we find that if we throw a stone upwards with a velocity of 32 feet per second it will rise to a height of 16 feet, and if with a velocity of 64 feet per second it will rise to 64 feet, and so on, these being the heights exactly from which it must fall in order to acquire the velocity of 32 or 64 feet per second with which it starts in its upward flight. Thus we see the attraction of the earth subtracts from it a velocity of 32 feet per second. To use the words of the mechanic, a stone propelled from the earth upwards proceeds with a uniform acceleration of—32 feet per second per second.

We have thus far considered only the movements of a stone thrown vertically or straight upwards ; we shall now study its movements when thrown somewhat off the straight line—at an angle, as it is called. In this case, instead of falling straight down to the earth again, it takes a peculiar curved path, something like that shown in Fig. 2, called a parabola, the result of the two forces acting on it. That there are two forces acting will be made clear by a glance at Fig. 2. Let A B be a small portion of the surface of the earth—so small, indeed, that it may be represented as flat, and not gently curved, as it really is. The stone is thrown skyward, at an angle, in the direction of A C, so that the line A C indicates the first force—the force of propulsion. But, during the flight of the stone, the force of gravity is acting upon it and drawing it downwards with an acceleration of 32 feet per second per second. Thus the line C D indicates the working of the *second* force, viz. that of gravity. The result of the contemporaneous action of these two forces is that the stone does not fly directly along the line A C, but, having its path modified by the force of gravity, proceeds along the curving path A E. The horizontal distance to which the body will attain before it touches the ground again depends on the force with which it is projected. Thus a cannon-ball shot out with a great velocity will go very much further than a stone thrown by the hand at the same angle. Thus we may imagine the force of projection to be increased to such an extent that the stone or ball would go right round the earth in a circle without touching it. Now, in this case we can easily see that the attraction of the earth only causes the stone or ball to take a circular path ; it takes nothing from the original velocity, for the body in the case supposed never alters its distance from the earth, and we have seen that it is only when the earth's attraction acts against the body rising from its surface that the velocity is lessened. The stone or ball therefore will, after going right round the earth, still have the same velocity as at starting, consequently it will continue to revolve round and round for ever. The stone is continually, as it were, attempting to fly away in a straight line, but the attraction of the earth restrains it and guides it into a circular path, just like a stone in a sling, the string of the sling acting the part of the earth's attraction in restraining the stone while it is whirled round in a circle. The force with which the stone tends to fly away from the earth is termed "*centrifugal* force," and it is very evident that to keep the stone revolving round the earth the centrifugal force must be exactly balanced by the force of attraction, for, if the former were stronger, the stone would fly off into space, and, if the latter, it would be drawn onwards to the earth. For instance, if a body is projected vertically upwards with a velocity of 472 miles per minute, gravity will never be able to restrain it, but it will pass away into space and never return ; if projected at an angle with the same velocity, its path will be a parabola, but it will never return to the earth ; if with rather less velocity, it will revolve round the earth in an ellipse of immense extent. As the initial velocity is reduced the curved path will be less and less, till it revolves in a path nearly circular when the two forces are nearly balanced.

It must be noticed, however, that all the laws we have traced out are only strictly correct when the movements take place in a vacuum ; they are greatly modified by the resistance and friction of the atmosphere. In falling through the air we find a stone does not fall at the same rate, neither would the same force cause it to go completely round the earth if it had to pass through the air. In fact, unless the force were so great as to drive it beyond the atmosphere altogether, it must sooner or later fall in upon the earth. The importance of this fact will be recognised as we proceed.

The next point we must consider is the effect of distance on this force of attraction. Would a stone, for instance, falling at a height of a mile or two above the earth's surface, acquire a velocity of 32 feet per second, as happens when it is near the surface? This point has been settled by experiments at different heights, made with the pendulum, which in reality vibrates on the same principle as a stone falls. It is found that the force of gravity diminishes exactly as the square of the distance from the earth's centre increases. Thus at twice any distance from that centre the attraction is only one-fourth, at three times the distance it is one-ninth, and so on.

Further, it has to be observed that all bodies, whatever be their mass or quantity of matter, follow these same laws of gravity; thus cork falls as rapidly when unopposed by the air as lead does. This shows that the attraction of gravity is proportional to the mass of falling body, for it is clear that if a body of two pounds weight moves at the same speed as a body of one pound weight, the force exerted in the former case is double that of the latter.

Another curious result of the action of gravity is this: when we project a stone into the air we actually move the world. There are familiar instances of this principle all round us. A shot fired from a gun or cannon causes the latter to "kick," or recoil, as it is termed—the force of projection acts equally in driving the bullet forward and the gun backward; similarly, when we throw a stone into the air we, at the same time, as it were, kick the earth in the other direction, and when the stone returns again, drawn down by the attraction of the earth, it also attracts the earth to itself, and the approach is mutual. There is a point between the centre of the earth and the stone called the centre of inertia, which never varies its relative distance from the centre of either. We may form some idea of this from considering a long lever rod with a small weight at one end and a large one at the other, and supported at a point between them so that they are exactly balanced. If we move the smaller weight to or from the point of support, we must also move the larger one in the same way, proportionately to its size. This gives us some idea of the action of throwing a stone: the point of support must keep steady; the stone is represented by the smaller weight moving along the arm of the lever, and the earth by the larger, and we thus see that their movement must be mutual and inversely proportional to their relative masses.

When Newton had arrived at the knowledge of the laws of gravity here described, it naturally occurred to him that as gravity did not cease to act even at a considerable distance above the surface of the earth it might continue to act at great distances in space, and he directed his attention first to the moon, as the nearest body to the earth, and yet not part of it. He thought it might possibly be, like the stone, projected with just such force that it revolved round and round the world for ever. We have observed that a falling stone is acted upon by a force tending towards the centre of the earth, and if the moon is really in the position of such a stone it must show by its motion that it is acted upon by a force proceeding from that centre, or appearing to do so; for we must remember it is not the centre that really attracts, it is the whole earth that does so, and the combined result is the same as if it all proceeded from the centre. Now, if the moon's path were exactly circular, the action from the earth's centre would be evident at once, for consider Fig. 3, where the outer ring represents the moon's path and C the centre of the earth. Suppose the moon at M as a falling body, acted on by the earth's attraction alone, falls, say in a second, to the point N; but it has centrifugal force from its original motion, which in that same time would carry it, say, to P. These two forces acting at once would, according to the well-known law of mechanics, carry

the moon M to the point O. Thus we should have evidence of the attractive force directed to the earth's centre. The moon's path or orbit round the earth is not, however, exactly circular; it is elliptical, or oval, from which it is evident the moon must be nearer the earth at certain times than at others. As the force of gravity increases the nearer bodies approach one another, it follows that the moon would be drawn into the earth altogether when it

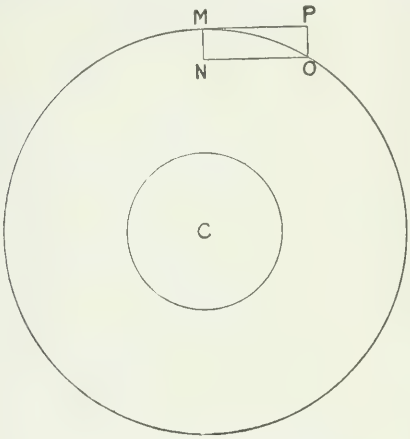


FIG. 3.—ILLUSTRATING THE EFFECT OF THE FORCE OF GRAVITY IN THE MOON'S ORBIT ROUND THE EARTH.

M, the moon. C, the centre of the earth.

came nearer, unless there was some counteracting influence. This is found in the increased speed with which the moon travels in its course when coming nearer the earth, and that in a certain regular manner which the law of gravity requires in a body moving round a fixed centre. Fig. 4 will make this plain. Suppose a body moving in a straight line, A B, at a certain fixed rate, it is evident it will travel equal distances, along the line in equal times. If we take these equal distances and join them to the centre S, geometry tells us that the various triangles, A S C, C S D, etc., will also be equal to each other. Now if, instead of moving along a straight line, the body is drawn in towards the centre, the law of motion by which a body neither loses nor gains, and the law of gravity, require that the new triangles formed should be equal to the former ones, so that the increased space passed over by the body when it is nearer the earth should exactly make up for the diminished distance from the earth. Thus the triangle A S E must be equal to the triangle A S C, etc. This is found to be the case with the moon in its motion round the earth, and is usually stated thus. The line joining the centres of the earth and moon describes equal distances in equal times.

Thus far the moon seems to obey the laws of gravitation already described, but more must be proved. It is necessary to show that the force of gravity at the distance of the moon from the earth is exactly equal to what we have called the centrifugal force, or the tendency the moon has to fly away in a straight line into space. The centrifugal force can be easily found out by observing the moon's speed. In making this calculation at first, Newton found that the two forces did not balance each other, and, as an evidence of his exceedingly scientific mind, he for a time laid aside his theory, as facts were against it—a truly noble lesson for all scientific speculators who are only too apt to try to wrest facts so that they square with preconceived theories, instead of making their theories square with facts. An error in the supposed distance of the moon, however, having been discovered, Newton saw at once that with this corrected his theory would be in complete accordance with the facts. It is related that he was so excited by the circumstance that he was unable to finish his calculations, and had to get a friend to do it for him.

We have mentioned that the moving path round the earth is not circular, but elliptical, or oval. This also necessarily follows from the laws of gravitation. For suppose the moon at such a distance from the earth that its speed is reduced so much as no longer to possess sufficient centrifugal force to balance the earth's attraction, it will necessarily commence to

fall towards the earth like a stone, and, according to the laws we have traced, its speed will increase. It can be easily shown that this speed will increase the intensity of the centrifugal force faster than the attraction of gravity increases by the approach to the earth, consequently the moon will commence again to recede from the earth, and this backward and forward movement generates the peculiar path it takes.

The great secret of the universe is thus fairly discovered, and only the details require to be worked out, for the moon's path round the earth is, on a smaller scale, what the paths of the planets are round the sun, and the solar system is by every principle of analogy representative of the vaster systems of the fixed stars. All are governed by what seems the fundamental principle of matter, viz. that *every body attracts every other body with a force proportional to their masses, and inversely as the square of the distances between their centres.* This great general law supplies us with the key with which we can unlock every difficulty, and enables us to predict with almost absolute certainty the movements of the heavenly bodies. In no case

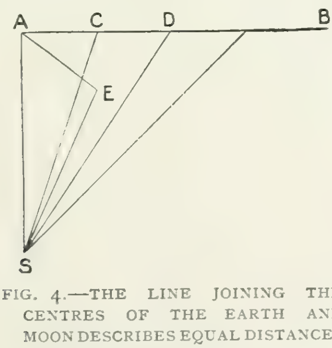


FIG. 4.—THE LINE JOINING THE CENTRES OF THE EARTH AND MOON DESCRIBES EQUAL DISTANCES IN EQUAL TIMES.

has it failed, or seemed to fail, though tested in every possible way.

What we have already learned from the fall of a stone, though important enough, by no means exhausts the subject. There is another field of inquiry developed in more recent times to which this phenomenon naturally leads us. We noticed that the stone in falling accumulated, so to speak, the force of gravity in itself, so that it would go on moving were the earth's attraction removed after it was in motion, the only difference being that there would be no *acceleration*, but only a regular *velocity*, that is providing that no other force impinged upon the stone. We noticed also that the stone was, of course, stopped in its course when it struck the ground. The question arises, what becomes of the force with which the stone was descending? All visible motion ceases; is the force therefore entirely lost and annihilated? The answer to this question is the greatest advance, perhaps, that science has made in modern times. It had always been observed that hard bodies, such as stones, when sharply struck one against the other, emitted light, but the full significance of this fact was not perceived for a long time. The light and, of course, the heat developed with it are found to be the exact equivalent of the force of the collision of the bodies. When, therefore, a stone falls to the ground the visible motion is not lost, but is entirely changed into the invisible motion of the particles of the stone which we term heat. We find, therefore, that when the stone is arrested in its course its temperature is raised, and there is always an exact relation between the distance fallen and the amount of heat. This relation has been carefully studied and measured, and it is found that when a pound weight of any body falls through a space of 772 feet by the earth's attraction it generates enough heat to raise one pound of ice-cold water 1° Fahr., or 772 lb. falling through one foot generates the same quantity of heat.

This has been called the "mechanical equivalent of heat," because it enables us to measure the value of heat in mechanical work, and is of great importance in the practical application of heat to the driving of machinery.

Since the fall of a stone upon the

earth generates a certain amount of heat, we may imagine the fall of an immense number of such stones generating so much heat as to cause the earth to glow and shine as the sun does with its own inherent heat. Nor is it necessary that the fall should be rapid and over in a short time, for, as a certain amount of motion is always represented by its equivalent in heat, we may imagine these stones falling together towards the centre of the earth in a very slow manner, but clashing among themselves, and having the appearance from the outside of a gradual contraction in volume, the heat and glow still being kept up for a length of time. According to this theory it is possible that the heat of the sun has its source in this action of gravity, gradually contracting its volume, and giving out its force as heat and light. If this be so, then we have another evidence of the wide dominion of the laws of gravity in the light of the stars; for if the sun's light and heat be due to this cause, that of the stars must be due to the same all-pervading force.

In such immense bodies as the sun and the fixed stars a contraction in volume scarcely perceptible for many ages would supply a sufficient quantity of heat to keep their light practically undiminished.

The principles involved in the fall of a stone throw light on another strange and puzzling class of bodies belonging to the solar system. We mean the comets. These bodies revolve round the sun in very eccentric elliptical paths, and this, we have seen, is the kind of path a stone would take if hurled with sufficient velocity from the surface of the earth at an angle from the vertical or straight upward direction. They may, therefore, have been projected from the body of the sun by the action of its internal forces. Their paths are governed strictly by those laws of gravity we have already described. It has been proved by spectrum analysis that these bodies not only reflect the solar light but shine from their own inherent high temperature, and it has been suggested by Professor Tait that this temperature may be explained by the supposition that comets are composed of nothing more or less than showers of stones rushing among themselves with various velocities, thus causing collisions and raising their temperature. He further suggests that the tails are formed of stone-dust, as it were thrown off by the force of the collision, just as showers of sparks are thrown off by the friction of the brake on a railway train. He has also ingeniously shown how the peculiar shape of the tail directed sometimes to, and sometimes from, the sun, may be accounted for by the combined motion of the comet in its path and the direction in which the sparks or stone-dust are thrown off.

The last point we shall notice is a purely speculative one, but at the same time of great philosophic interest. So far as we have studied the movements of the universe there appears no reason why these movements should not go on for an indefinite length of time. It has been said by a scientific writer, regarding the geological history of the world, that "There is no trace of a beginning, and no prospect of an end."

In speculating on this point, however, there is one consideration to be kept in view, which may point out to us an inevitable end to the present state of things. In this paper we stated that unless the force with which a stone was projected from the earth was so great as to carry it beyond the atmosphere altogether, it must sooner or later fall in upon the earth. The reason for this is that the friction of the atmosphere acts like a brake, gradually reducing the velocity, and, of course, as the velocity is reduced the centrifugal force also becomes less, until it is no longer able to balance the attractive force of the earth, and the stone falls to the ground.

It becomes interesting in this view to inquire if there is anything like an atmosphere in celestial space acting on the heavenly bodies as the atmosphere on the

stone, and gradually bringing them to rest round one common centre. There is considerable probability for concluding that there is such an atmosphere. In the first place, one comet, at least, has given evidence of encountering some resisting medium in its course ; very rare indeed the medium must be, but still possessing some resisting power, which in the course of ages must inevitably cause the comet to be carried into the sun. Again, the modern researches on light and heat, proving these to be waves of motion passing from one body to another, seem to necessitate the existence of some medium through which the waves may be propagated, and as light comes from the stars as well as the sun it seems that the medium must extend throughout all visible space.

If such be the case, the conclusion is inevitable that the whole visible creation must gradually gravitate towards one common mass. Planets losing their velocity will in the course of ages be drawn in to their central suns, causing these to blaze up again with renewed splendour for a time, from the heat generated by their inward rush. Suns will be drawn towards suns, but ever with lessening light and contracting mass.

Thus we see that gravity, while it is the mainspring of the movements and order of the universe, will also be, if present laws hold good and if we have read them aright, the sure cause of its inevitable decay and death. The heavenly bodies may, indeed, be regarded as falling stones, ever falling closer and closer, generating by their energy those orderly paths and systems and those life-giving waves of heat and light, but surely tending downwards to a state of rest and decay, when all motion, all life, all light, will depart, and leave the huge inert mass in darkness and death.

THE MAN IN THE MOON.

THE irregular markings on the face of the moon attracted attention long before the invention of the telescope, and seem from very early times to have been regarded as forming the features of an imaginary face. We find several references to this imagined face in writers of antiquity. In some cases the features recognised were those of a man, in others of a woman. The "man in the moon" of later days seems to have been usually pictured as a man bearing a large bundle of sticks on his shoulders, and accompanied by a dog. In some parts of rural Scotland there is a quaint old superstition that the unlucky individual who is described in Holy Writ as having been caught gathering sticks upon the Sabbath, was put up in the moon for punishment as a warning for all time to offenders, seeing that he was doomed to carry his bundle of ill-gotten sticks all through the ages. In this case the dog, the faithful sharer of the stick-gatherer's travail, seems to have been forgotten. But those who have not heard of the sticks and dog, generally imagine a face only in the full moon. If the picture of the moon shown in Fig. 3 is held at a considerable distance from the eye, the general appearance presented by the full moon is shown. Then the dark parts O and G are the eyes of the full-faced man in the moon, the eyebrows sloping downwards and rather heavily marked; the mouth occupies the lower part of the dark marking S and T; and the other features fall correspondingly. The full figure of a man with his bundle of sticks and little dog is generally formed thus: H is his head, O and G are the parts of the bundle on either side of his shoulders, his legs lie on the dark marking S, and T is the little dog.

It is, however, important to notice that from the very earliest times men have recognised always the same features in the full moon. They have also found that, as the moon waxes and wanes, the same features are still seen as far as the illumination extends. In other words, men have known from time immemorial that the moon in her circuit around the earth turns always the same face towards us. This is in reality one of the most remarkable circumstances known about the moon, though its significance has been recognised only in recent times.

The study of the moon's disc with the naked eye did not reveal any facts of interest respecting the moon's physical condition, though carried on for thousands of years, and by some among the chief astronomers of antiquity. The views held by Anaxagoras five hundred years before Christ were in the main the same as those held by Copernicus, and by Galileo himself until the eventful year 1609, when he first turned a telescope upon our satellite. It was supposed that the markings indicated the presence of lands and seas, valleys and mountains on the moon, that she is a globe in many respects like our earth, and has probably been the abode of life.

But even before the invention of the telescope many important facts were discovered respecting the moon's motions. Such researches, carried on successfully from the time of Hipparchus to that of Galileo, were continued thereafter, becoming more and more exact as instrumental appliances were improved, and culminating in our present very exact knowledge of the moon's distance, size, motions, and perturbations. In an account, therefore, of the planet Luna, as known from phenomena, the consideration of

these points naturally precedes that of her physical condition.

The earliest observers noted that when the moon is opposite the sun she shines with a full disc; that when near him in the sky she shows only a fine crescent of light, with the horns turned from the sun; and that her disc gradually fills as she recedes from the sun's place in the heavens, and gradually becomes less and less fully illuminated as she approaches him. They could thence readily infer that she must be a globe illuminated by the sun, and very much nearer to the earth than the sun is. There is no simpler or better proof of this relation than the following. Let S, Fig. I, be a lamp lighting a room not otherwise illuminated; M a small white globe attached to a bent wire, M E H, held in the hand, H, of the observer. Now let the wire be slowly twirled, the part E H remaining upright, so that the ball M moves round through the positions I, 2, 3, 4, etc., to 8. Then if the observer so move his head as to look at the ball M always along the arm E M (or as nearly in that direction as he can, for when M is near 5 his head will be in the way of the rays from the lamp if he looks exactly along the arm E M), he will see the ball passing through all the phases of the moon—dark at I, a crescent of light at 2, one-half bright at 3, three-quarters bright at 4, all bright at 5, three-quarters bright at 6, one-half bright at 7, a crescent of light at 8, and dark again at I. Since he looks always in the same direction as a small observer placed at E would look, it is clear that an observer at the centre of the circuit of the small globe M would see that globe passing through all such phases as the moon passes through. It follows that the moon's phases are explained by supposing her as a globe M circling round the place E, corresponding to the home of the terrestrial observer, and illuminated by a more distant light S, answering to the sun. It is also easily seen that no other explanation is available. Hence we learn that the moon is an opaque globe circling round the earth, that she is illuminated by the sun, that she is much nearer to us than the sun, and therefore, since she looks no larger, that she is a much smaller globe.

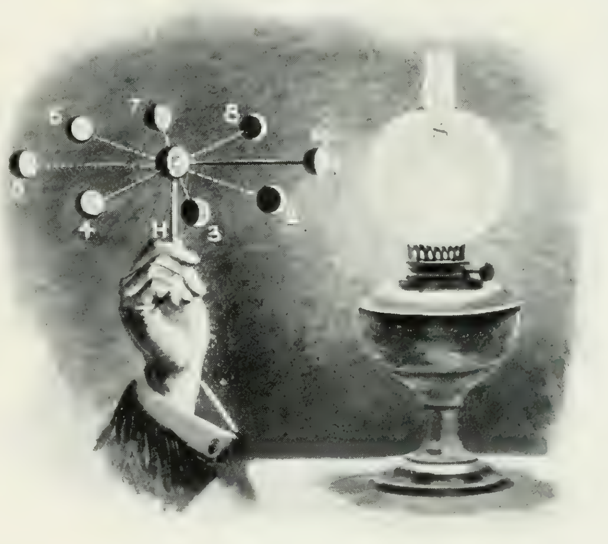


FIG. I.—ILLUSTRATING THE PHASES OF THE MOON.
The lamp represents the sun; E, the earth; and the balls marked 1-8 the moon in its various positions.

We must next briefly consider how, by watching the moon, the early observers ascertained the general laws of her motion. In so doing we are, in fact, going back to the very beginning of astronomy; for there can be little doubt that the moon's motions were studied and timed long before the apparent motions of the sun, planets, and stars were examined or even noticed. The passage of the moon through the four quarters of her seeming circuit—that is,

from invisibility to half-full, from half-full to full, from full to half-full, and from half-full to invisibility—gave the week as a measure of time, though men must soon have noticed that the lunar month does not contain exactly four weeks. Probably at first the time when the moon is invisible was regarded as marking a separation between successive months, and the rest of the month was divided into four quarters, each a week long, a usage of which traces remain in the Jewish festival and day of rest of the "new moon." Later the regular succession of weeks came in, the length of the lunar month being more exactly determined. It was found to be 29 days 12 hours 44 minutes. This is the *lunation*, sometimes called the *synodical month.*

Tracking the moon's course round the heavens, men found that it lies along a certain zone about $10\frac{1}{3}°$ wide, the central line of which is the sun's track (though this was only noted later). Most of the first observers seem to have divided this zone into 28 equal parts, called lunar mansions, each corresponding very nearly with the moon's motion among the stars during a single day. Closer observation showed, however, that she really completes the circuit of the stellar heavens in 27 days 7 hours $43\frac{1}{5}$ minutes. This is the *sidereal month.* It is easy to see why it is shorter than the common lunar month. To complete a common month the moon has to go round the heavens from the sun to the sun again, and the sun is all the time advancing slowly in the same direction. The sun takes one year to go once round the heavens, so that in a lunar month of $29\frac{1}{2}$ days he completes rather less than a twelfth part of a circuit; thus in a common lunar month the moon goes once round the stellar heavens and rather less than one-twelfth of a circuit *more.* The common lunar month, then, exceeds the sidereal month (in which she completes one circuit of the stellar heavens) nearly as one and a twelfth exceeds one.

In making these observations, the first astronomers could not fail to note the occurrence of eclipses, both of the sun and moon. Nor could they fail to understand the cause of eclipses. The explanation of the phases, as illustrated in Fig. 1, shows also why eclipses occur; for when the globe M is at 1 it is seen by an eye looking along the rod E M as a black disc on the face of the lamp S, just as the moon is seen as a black disc hiding more or less of the sun's face in a solar eclipse. On the other hand, when the globe is at 5 and the observer looks directly along the rod E M, his head comes between the lamp S and the globe M, throwing a shadow upon it, just as, during an eclipse of the moon, occurring always when she is full, the shadow of the earth is thrown upon her. At present space will not permit the details of these eclipses, or the measurements of the moon's distance from us, her size, and weight to be given. It is only necessary to state here the results to which such inquiries have led. It has been found, then, that the moon travels at a mean distance of 238,840 miles from the earth's centre, on a path nearly, but not quite, circular, and also varying slightly from time to time in shape. The moon never, under any circumstances, approaches the earth within less than 221,610 miles, or recedes from her more than 252,970 miles. The breadth of the moon's face varies accordingly. When nearest to the earth (or in *perigee*, as it is termed), she has an apparent diameter of $33\frac{1}{2}'$; when farthest (or in *apogee*), her apparent diameter is $29\frac{1}{3}'$; her average apparent diameter is about $31'$, or about $1'$ less than the average apparent diameter of the sun. Her real diameter is about 2,160 miles, not much more than a fourth of the earth's; her surface 14,600,000 square miles, or between a thirteenth and a

fourteenth of the earth's. The earth's volume exceeds the moon's nearly $49\frac{1}{2}$ times. But the moon's material is either lighter or less compressed than the earth's, for the earth's mass exceeds hers, not $49\frac{1}{2}$ times only, but nearly $81\frac{1}{2}$ times. Her mean density, in fact, is almost exactly three-fifths of the earth's, and about $3\frac{1}{2}$ times greater than the density of water — if the earth's weight has been rightly measured.

Such is the globe on which those markings appear which have given rise to the conception of a "man in the moon." It is necessary to remember these dimensions in considering the markings, for otherwise we should form very imperfect ideas of their real nature. Noting that half the moon's apparent diameter is about 1,000 miles, we have a ready scale by which to estimate the dimensions of any lunar marking; only, of course, it must be remembered also that the face of the moon is not a flat circle, but one half of a globe, so that the parts near the edge are very much foreshortened. I have already stated that the moon turns always the same half towards us. Speaking generally, this is true; but it is necessary to explain that we can see rather more than half of the moon's surface. She turns on her axis once while circuiting once round the earth in the same direction. If *both* motions were uniform, and both in the same plane, she would turn always the same face exactly towards us. But, whereas she turns uniformly on her axis, she travels round the earth with slightly varying speed. Thus her motion of revolution at one time gains, at another loses, on her motion of rotation, the effect of which is that at one time she appears as if rotated a little backwards, and at another as if rotated a little forwards, from her mean

Photo: J. W. Taber, San Francisco, U.S.A.

FIG. 2.—THE MOON AS SEEN WHEN A FEW "DAYS" OLD.

position; so that two fringes of her surface, one on the west and the other on the east of her medium face, are brought into view. This is called the *libration* (or swaying) *in longitude*. Again, her axis of rotation is not quite upright or at right angles to the plane in which she travels, so that we sometimes see a portion of her surface beyond her northern pole and a narrow northern fringe beyond her medium face, and at other times a narrow southern fringe. This is called the *libration* (or swaying) *in latitude*. In this way, and by viewing her from different parts of the large globe of the earth, we see about

59-hundredths of her surface instead of only 50-hundredths, as we should if there were no libration and the earth were very small. All sorts of conjectures have been made as to what is to be found upon this hidden part of our satellite's surface, this unknown 41-hundredths which no earthly eye has seen. It is probable, of course, that the hidden is not different from the revealed surface, and therewith we must rest content.

It ought also to be noticed before we consider the condition of the moon's surface as shown by the telescope that the force of gravity at her surface is very much less than at the earth's. The quantity of matter which on earth we call one pound would at the moon's surface tend downwards only with the same force as about 2 oz. 10½ drams at the earth's surface; and a body let fall from a point not far above the moon's surface would in the first second fall through only 2 ft. 6 in., instead of 16 ft., as happens with a body falling to the earth.

One of the first discoveries made (by Galileo) when the moon was examined with a telescope, was that the dark markings forming the features of "the man in the moon" are not seas, as had been supposed by Kepler and others, but portions of the solid surface of the moon, which, indeed, so far as can be judged, seems to be an entirely solid globe. Strangely enough, however, these dark regions, which are still called seas, correspond precisely with the regions which would be oceanic if there were water on the moon. They are great plains, lying at lower levels than the brighter parts. The expression "lower levels" is used advisedly, for it has been shown by the German astronomers Beer and Mädler that these enormous plains are not all at the same level. Each also has its own peculiar character or tint. When they are spoken of as plains it is not to be understood that they are perfectly level. There are portions of some of these seas which seem as level as the smoothest prairies in America; others are more undulating; all show signs of having a rough real surface. But they are plains in the same sense that any wide districts of our earth where the variations of height above the sea level do not amount to more than a hundred feet or so are spoken of as plains. The general idea conveyed by their appearance under the telescope is that they are old sea-bottoms.

These peculiarities of surface contour, and the fact that the low level plains are darker than the high mountain regions, are highly significant. They seem to speak unmistakeably of long eras of time during which water existed on the moon, and enormous quantities of earthy matter like those which form the darker "rocks" of our own earth were deposited at the bottom of the lunar oceans, seas, and lakes, while wide tracts of alluvial matter were formed at the mouths of the chief lunar rivers.

The map of the moon forming Fig. 3 represents her as she appears in an ordinary telescope for viewing landscapes, so that she is not inverted as with the astronomical telescope. The points marked E and W are not the east and west points of the moon as they appear to an observer on the earth, but as they would appear to an observer on the moon itself. Thus to us the point marked N E indicates the north-west quadrant of the moon, E the west, and S E the south-west.

The two eyes of the "man" are formed by the Sea of Showers (O) and the Sea of Tranquillity (G). The latter is to the eye the darkest large tract on the moon's surface, though in photographs of the full moon the Sea of Serenity (H) appears quite as dark. The Sea of Vapours (L), the Bay of Tides (or Heats) (N), and Mid-Moon Bay (M), form the nose, whose somewhat "tip-tilted" form is outlined by a range of mountains bounding the Sea of Showers

Photo: The Taber Photographic Co., San Francisco, U.S.A.

FIG. 3.—THE FULL MOON.

A. The Sea of Conflicts (Mare Crisium).
B. Humboldt's Sea (Mare Humboldtianum).
C. The Sea of Cold (Mare Frigoris).
D. The Lake of Death (Lacus Mortis).
E. The Lake of Dreams (Lacus Somniorum).
F. The Marsh of Sleep (Palus Somnii).
G. The Sea of Tranquillity (Mare Tranquillitatis).
H. The Sea of Serenity (Mare Serenitatis).
J. The Marsh of Fogs (Palus Nebularum).
K. The Marsh of Corruption (Palus Putredinis).
L. The Sea of Vapours (Mare Vaporum).
M. Mid-Moon Bay (Sinus Medii).
N. The Bay of Tides (Sinus Æstuum).
O. The Sea of Showers (Mare Imbrium).
P. The Bay of Rainbows (Sinus Iridum).
Q. The Ocean of Tempests (Oceanus Procellarum).
R. The Bay of Dew (Sinus Roris).
S. The Sea of Clouds (Mare Nubium).
T. The Sea of Liquids (Mare Humorum).
V. The Sea of Nectar (Mare Nectaris).
X. The Sea of Fecundity (Mare Fœcunditatis).
Z. The Southern Sea (Mare Australe).

LUNAR RING-MOUNTAINS AND CRATERS.

1. Tycho.
2. Copernicus.
3. Kepler.
4. Aristarchus.
5. Plato.
6. Linné.
7. Archimedes.
8. Aristotle.
9. Theophilus.
10. Ptolemæus.
11. Schickard.
12. Gassendi.
13. Grimaldi.

on the south-west, and called the Lunar Apennines. The mouth, rather wide and gaping, is formed by the Sea of Clouds (s). The rest of the face can be filled in by the imagination.

If the telescope gives evidence of the past action of water on the moon, much more clearly does it bring into view the signs of former volcanic activity. The Lunar Apennines have been mentioned. Ranges such as these are not the most remarkable features of lunar mountain scenery. The lunar mountain chains show, like those of the earth, a greater steepness on one side than on the other—the side towards the so-called seas being the steepest, precisely as the Pacific slopes of the Andes and Rocky Mountains and the southern slopes of the Himalayas are steeper than the slopes tending to the wide extent of continent on the east of the American and on the north of the Asiatic chains. Scattered mountains, hills, and rocks are numerous, some of them standing on the plains in solitary grandeur. According to some observers, the steepness of the sides of some of these detached elevations is only equalled among the terrestrial regions most remarkable for the height and abruptness of their mountains.

But the most remarkable of all the lunar features are the ring-mountains or great craters. These are not only much larger relatively to the moon's smaller globe, but much larger absolutely, than the largest craters on our own earth. They also are differently shaped. Terrestrial craters are usually comparatively small openings at the top of large, conical mountains. In the moon, the raised ring surrounding the crater rises to a relatively small height above the surrounding slopes and the enclosed flat bottom, while some of the chief craters have a span of many miles. Astronomers commonly arrange the lunar ring-shaped cavities into three classes—walled plains, ring-mountains, and craters. The walled plains appear to have been formed first by volcanic fires upheaving a large region, and forming all round it a ring of raised rocky matter, while later the interior seems to have been invaded by liquid matter from without, carrying in and depositing substances of the same kind as those which form the surface of the so-called seas. The ring-mountains are smaller, and the craters yet smaller. Some observers add, as a fourth class, small saucer-shaped depressions not girdled by a ring raised above the surrounding plain.

The thirteen ring-mountains and craters numbered in Fig. 3 will suffice to give a good idea of these remarkable objects.

No. 1 is the great circular mountain Tycho, which may be compared to a great carbuncle on the chin of "the man in the moon." It is the centre of a wonderfully irregular mountain region, over which lie hundreds of craters and ring-mountains, while from Tycho itself radiations extend in all directions, some reaching to enormous distances. Nasmyth compared these to cracks in a globe which has been burst by the expansion of matter within it, or (which comes to the same thing, and probably corresponds more closely with what has actually happened in the moon's case) by the contraction of the globe upon unyielding matter within. In objection to this view it has been advanced that if the shell of the lunar globe was burst in this way, the cracks would not have closed so exactly that no shadows would be thrown along them; and no shadows are seen along the streaks of bright surface radiating from Tycho. But it seems probable that if, through the mighty openings thus formed, liquid lava were poured out, it would flow all over the opening along the cracks, and would have, while liquid, and retain after cooling, a nearly level surface throwing no perceptible shadows. At any rate, there seems no other way of accounting for the radiations from Tycho

and a few other craters than one involving the action of volcanic forces. Nasmyth's cracked globe theory seems to indicate the most natural way in which such radiations could be accounted for. The wall

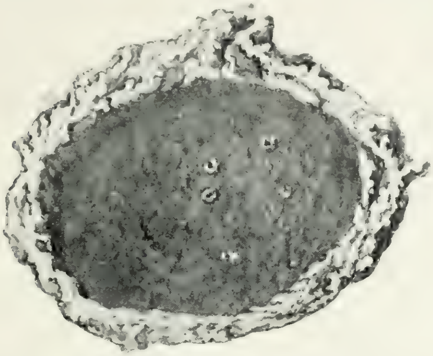


FIG. 4.—THE RINGED LUNAR MOUNTAIN PLATO AT MID-DAY IN THE MOON.

of Tycho rises to a height of nearly three miles, or, more exactly, about 16,600 feet —816 feet greater than the height of Mont Blanc. The diameter of the circular enclosed space is more than 50 miles, so that the area of this space is about 2,000 square miles. In the middle there is a mountain about 5,000 feet high.

The crater Copernicus (2) is still larger than Tycho, having a diameter of 56 miles. Its central mountain, which has six heads, attains in its two highest heads a height of about 2,400 feet. It is manifest from the appearance presented by this crater as the boundary between the light and dark parts of the moon passes over it both in advancing and in retreating, that the whole crater stands high above the mean level of the moon's surface. In this respect it seems to be an even more important formation than Tycho, though the radiations from Copernicus do not extend so far as those from Tycho. Under full illumination Copernicus appears as a large, ill-defined white patch (on the left of "the man in the moon's" nose). The floor of Copernicus is about 11,000 feet below the ridge of the surrounding ring.

Before passing from this important and characteristic lunar crater, it may be well to notice that, while the radiations from Copernicus illustrate Nasmyth's theory of the action of the nuclear matter upon the contracting crust of the moon, the region around Copernicus illustrates in another way a later process, which has left almost equally well-defined traces of its action. If we consider the moon at that particular stage of her past history when a continuous crust had first formed around the molten matter forming her nucleus, we perceive that there would be two well-marked periods of progress from that stage. During the first, the outer crust would cool more rapidly than the nucleus, radiating its heat freely into space. Consequently, the crust would contract upon the nucleus, and from time to time would be compelled to give way at various points of its extent, a series of radiating cracks appearing round the region where the crust had yielded.

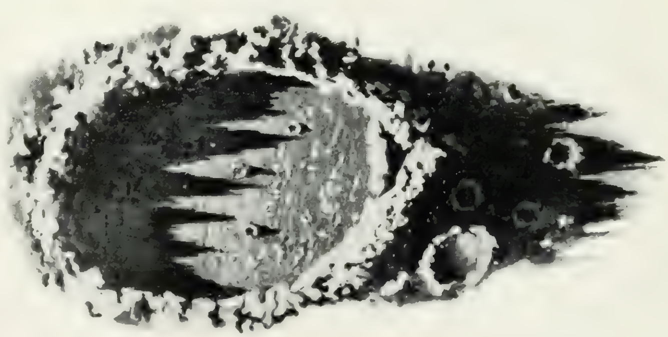


FIG. 5.—"PLATO" IN EARLY MORNING IN THE MOON.

But after a time the crust, having already greatly cooled, would no longer cool so rapidly. The heat poured from it into space would be compensated, or nearly so, by the heat which it would receive from the cooling nucleus. Thus the nucleus would now in its turn cool more

rapidly than the crust. The nuclear matter would therefore shrink from the crust, which, yielding to the action of lunar gravity, would contract in such a way as to form surface corrugations. Nasmyth mentions the shrivelled skin of a dried apple and the wrinkles of loose skin upon a lean and shrunken hand as illustrations of the corrugations thus formed. Now, over the region around Copernicus the corrugations of the lunar crust are singularly well shown. Whether it be that the same circumstance which causes the crater itself (to its very base) to be far higher than the mean level of the moon's surface has favoured the formation of these corrugations, or whatever may be the true explanation, certain it is that they are especially numerous, complex, and well defined, over the whole region around this fine crater.

Another interesting peculiarity of the moon's surface is well shown in the region around Copernicus—the immense number of small craters. Some observers have been disposed to believe that some among these craters—at least the smallest—may have been produced by a cause quite different from that to which unquestionably all the large craters, and most even of the small craters, must be assigned. When we remember that even at this day millions of meteoric masses, of greater or less size, fall upon our earth every year, and that necessarily more than one-fourteenth as many fall on her companion planet the moon (which presents to matter outside a surface equal to rather less than one-fourteenth of the earth's), we perceive that in remote ages, when as yet the supply of meteoric matter had not so nearly approached exhaustion, the downpour of meteors on both the earth and the moon must have been far heavier than at present. Combining this consideration with the circumstance that during many thousands of years the moon's crust must have been so heated as to be plastic to receive impressions from without, yet firm enough to retain them, it can scarcely be doubted that the moon's surface must show some marks due to the downfall of the larger meteoric masses in that long period of her past existence. Anyone who studies carefully the region around the lunar crater Copernicus with a powerful telescope will not fail to recognise many minute pits, whereof some at least may fairly be explained as due to the downfall of meteors of the larger sort.

Kepler (3), a crater about 22 miles in diameter, is the centre of another great ray-system intersecting that of Copernicus in such a way as to suggest that Kepler is the later formation. The interior is depressed about 10,000 feet below the top of the ring.

Aristarchus (4) is a ring-mountain about 28 miles in diameter, the ring rising some 7,500 feet above the floor. Within is a mountain of singular whiteness. The ring being also very bright, the entire crater is visible to the naked eye as the brightest small spot on the moon's face, Copernicus being, however, on the whole, more conspicuous. In the telescope the central mountain can be seen even when it lies well within the dark part of the moon's disc. Sir W. Herschel mistook it, under these circumstances, for a volcano in eruption, but doubtless the light with which it then shines is simply reflected earth-light. For it must be remembered that the earth shines in the lunarian skies as an orb more than thirteen times larger than the moon appears to us, and probably giving nearly twenty times as much light.

Plato (5) is one of the most interesting of the lunar ring-mountains. It was formerly called the Greater Black Lake, on account of the darkness of the enclosed plain. This plain is nearly circular, about 60 miles in diameter, and contains about 2,800 square miles. The ringed wall varies in height from 3,800 to about 7,300 feet on the western side, attaining

on the eastern side a somewhat greater height. The floor is not uniform in tint, but, as shown in Figs. 4 and 5, presents slight variations, and contains several small craters. It has been supposed by some observers that the floor of Plato grows darker as the sun rises higher above its level. But the general opinion, at present, among astronomers, is that the supposed change is merely an effect of contrast. If we compare Figs. 4 and 5, one showing the ringed plain at the time of lunar mid-day, the other showing it soon after morning has begun there, we see how in the latter case (and similarly towards eventide) the black shadows cause the floor to look bright by contrast, whereas at mid-day in Plato the bright ring all round the floor causes the latter to look dark.

Linné (6), in the Sea of Serenity, is a much smaller object, but even more interesting. It was described by Lohrmann as "very deep," and by Beer and Mädler as "deep"; but in 1866 Schmidt noticed that Linné appeared as a mere whitish cloud. There seems (after considerable conflict and discussion) to remain little doubt that in some way, as yet not explained, the walls of this deep crater have been lately in great part prostrated.

Archimedes (7) is a spot not unlike Plato in size and shape, but presenting none of the peculiarities or seeming changes of tint which characterise Plato.

Aristotle (8) is a fine crater 50 miles broad and about 10,000 feet deep.

Theophilus (9) is remarkable as the deepest of all the lunar craters. Its diameter is about 64 miles, and the walls around range from 14,000 feet to 18,000 feet in height above the floor. There is a central mountain more than 5,000 feet high.

Ptolemæus (10) is the most northerly and the largest of a chain of ringed plains. It is no less than 115 miles in width.

Schickard (11) is an enormous walled plain 460 miles in circuit. Though the ring is in parts 10,500 feet high, it must be quite invisible from the middle of the plain, owing to the convexity of the moon's surface.

Gassendi (12) is a walled plain about 55 miles across; Grimaldi (13) is a great crater 147 miles long by 129 broad, and remarkable as having a floor darker than any portion of the moon of similar size. It can be seen, under favourable conditions, without a telescope.

Besides the features hitherto considered, the moon's surface presents under close telescopic scrutiny a number of valleys, ravines, gorges, and clefts or rills. Some of these last are very singular in character. As Webb remarks, they "pass chiefly through levels, intersect craters (proving a more recent date), reappear beyond obstructing mountains as though carried through by a tunnel, and commence and terminate with little reference to any conspicuous feature of the neighbourhood. The idea of artificial formation is negatived by their magnitude; they have been more probably referred to cracks in a shrinking surface." There are also closed cracks, sometimes of considerable length, where the surface is raised higher on one side of the crack than on the other, so that the displacement (of the same nature as what is called by miners a *fault*) can be recognised by the shadow thrown on the lower side.

From all the observations hitherto made upon the moon, it appears that she has a very thin atmosphere. When she passes over the stars these disappear and reappear quite suddenly; not fading gradually from view and coming as gradually into view again, as they would if the moon had an atmosphere of appreciable density. The absence of any atmosphere, save one of extreme tenuity, is also shown by the blackness of the shadows of the lunar mountains, and by other phenomena which need not here be considered.

As there are no signs of water on the moon's surface, we may reasonably conclude that her globe, waterless and airless, cannot possibly be the abode of any forms of life resembling those with which we are familiar on this earth.

The opinion has been entertained that on the farther and invisible part of the moon the 41-100ths of her periphery already referred to there may be air and water, and consequently that living creatures may exist there. But though there are many reasons for believing that the moon has not always been a waterless and airless globe, it is no longer supposed that her air and water have retreated to the farther side. The opinion more generally entertained is that, as the moon's interior cooled, the water formerly filling the lunar seas and bays retreated to the interior of the moon, soaking the moon's substance in the same way that water soaks the substance of pumice-stone and similar materials.

But it must be admitted that while the evidence showing the moon to be airless and waterless is clear, and while there are strong reasons for believing that the moon once had seas and probably an atmosphere much denser than her present atmosphere, it is not at all easy to form a satisfactory theory respecting the processes by which she attained her actual condition.

From observations which have been made with a view to determine the tint (irrespective of *colour*) of the moon's surface, it appears that, while the average reflective capacity of the moon is about the same as that of weathered sandstone, the grey plains are much darker, the bright raised regions much whiter. The darkest parts are as deeply tinted as our darkest earth, and the brightest spots almost as white as lately fallen snow. From the way in which the amount of the lunar light varies as the moon passes through her various phases, it is believed that her entire surface is in reality altogether rugged.

To sum up what we have learned about the moon: We find that she is a planet accompanying a larger planet, the earth, on its journey round the sun. Her diameter is about one-quarter, her surface about 2-27ths, her volume about 2-99ths, her mass about 2-163rds of the earth's. She completes a journey round the earth regarded as at rest in about $27\frac{1}{3}$ days, travelling at a mean distance of 238,840 miles; but the lunar month, or the period between successive conjunctions of the sun and moon, has an average length of about $29\frac{1}{2}$ days. The moon's surface may be divided roughly into raised parts which are usually bright, and great plains (not smooth) which are darker, and in some cases very dark. Over all the raised parts the signs of former volcanic activity are very marked, craters and ring-mountains, much larger than any existing on the earth, being found in great numbers on the moon's surface. Cracks and faults, deep valleys, ravines, and gorges, are numerous on the rugged surface of our satellite. No water and very little air seem present on the moon; though there are signs that seas formerly existed there, and there is reason to believe that the lunar air was once not very rare. There is nothing to suggest that our satellite is at present the abode of life. According to our conceptions, she is a dead world now, whatever she may have been in the past. The forms of life that may once have peopled her plains, and mountains, and ringed craters are gone. Her civilisations, if she ever had any, have gone, and the records they may have left behind them can only be dimly surmised until science bridges the caverns of space, and does in fact what the novelist has done in fancy—explored the rugged and time-worn features of "the man in the moon."

THE PROTECTIVE COLOURS OF INSECTS.

1a. Leaf-butterfly of India (*Kallima inachis*), with outspread wings. 1b. The same when at rest upon a twig. 2a, 2b. Butterfly resembling bird droppings on bark. 3. A Caterpillar similar in colour to bark. 4. Transparent-winged Butterfly, nearly invisible when flying. 5a, 5b One of the Peacock Butterflies partly concealed when at rest. 6. Leaf-insect (*Phyllium siccifolium*). 7. Stick Insect, protected by its likeness to a leafless twig.

THE PROTECTIVE COLOURS OF ANIMALS.*

TO the ordinary observer the colours of the various kinds of molluscs, insects, reptiles, birds, and mammals appear to have no use, and to be distributed pretty much at random. There is a general notion that, in the tropics, everything—insects, birds, and flowers especially—is much more brilliantly coloured than with us ; but the idea that we should ever be able to give a satisfactory reason why one creature is white and another black, why this caterpillar is green and that one brown, and a third adorned with stripes and spots of the most gaudy colours, would seem to most persons both presumptuous and absurd. The purpose of this article is to show, however, that in a large number of cases the colours of animals are of the greatest importance to them, and that sometimes even their very existence depends upon their peculiar tints.

It is an almost universal rule that each animal either has enemies which seek to feed upon it, or that it seeks itself to feed upon other animals. In the first case, it has to escape its enemies or it cannot long continue to live. This it does either by its swiftness of flight, by its watchfulness, or by hiding itself from view. Some species come abroad only at night, some burrow under ground, many hide themselves among leaves, or bark, or stones, and thus escape destruction. Their enemies, however, are as swift and as watchful as they are themselves, and they can in most cases only escape them by avoiding observation. To do this, they must not be too conspicuous ; and thus any kind of colouring that renders them hardly visible while seeking their food, or attending to their young, actually tends to preserve their lives, and often enables them to secure the safety of their offspring. But the enemy who is in pursuit of them is in just the same predicament. He, too, must be concealed by his colour, or he will be seen from afar, and his prey will seek a secure concealment. In that case he will simply starve to death, and his race will cease to exist.

It thus appears that almost every kind of animal requires concealment ; and it might therefore be thought that colour must always be injurious, and ought never to exist. And as colour not only exists, but abounds among the various classes of animals, it may be thought that we have here a *reductio ad absurdum*, and that protective colouring cannot be of much importance.

Further examination, however, shows us that even gay colours are very often protective, because the earth and the sky, the leaves and the flowers, themselves glow with pure and vivid hues. In other cases conspicuous colouring is useful to an animal ; thus, when it is protected by the possession of a deadly sting, as in the ease of the wasp and hornet, the bright or unusual colour warns its would-be enemies to avoid it. There are also great numbers of animals that appear to be sufficiently able to take care of themselves without resorting to concealment, and with these the tendency to the production of colour, which seems to be inherent in organic beings, exhibits itself unchecked.

Taking all these facts into consideration, we find that there is an ample field for the development of bright and conspicuous colour on the one hand, and for the display of an infinite variety of protective tints on

* This fascinating study may be further pursued in Mr. H. W. Shepheard-Walwyn's book "Nature's Riddles."

the other, dependent on the structure, the habits, and the instincts of the different kinds of animals.

The rabbit affords a good example of simple protective colouration. His russet brown coat harmonises beautifully with the bare earth or heather or withered grasses which abound in the places it most frequents. When suddenly surprised by the approach of an enemy, he either scampers hurriedly to his burrow, if that, or other shelter, is near at hand, or crouches low upon the ground, where he is almost sure to escape notice. This is the case even under somewhat artificial conditions. In the instance depicted in the accompanying illustration (Fig. 1), he has been caught unawares when trespassing upon a rose-bed, and he accordingly deems it best to flatten himself out on the ground. On this occasion the result is singularly happy, as the dead laurel leaves scattered over the earth are striking imitations of the rabbit's ear, and he remains well concealed till the danger has passed.

Photo: H. W. Shepherd Walwyn, Esq., F.Z.S., F.E.S.

FIG. 1.—A RABBIT IN A ROSE BED.

His brown fur harmonises with the dead leaves round about.

Let us now consider a few other familiar examples of protective colouring. One year my garden was overrun with slugs, and I had to wage continual war against them. On every damp evening I would go round the borders, examining the choicest plants, and, taking the slugs off with a knife, deposit them in a jar of strong brine. While doing this, many of them, on being touched, would contract and drop to the ground, and, though they fell close under my eyes, I often had some trouble to find them again, owing to their close resemblance to the small pebbles with which the soil abounded. They varied in colour from nearly white, to brown, yellow, and nearly black, and when contracted into an oval lump, they were exactly like the variously coloured wet pebbles. One black slug with an olive-yellow undersurface, when contracted, was wonderfully like a blackish flint pebble broken in two, showing the yellowish inside so common in such stones. It may be said that this was only an accidental resemblance, and at first it did not strike me as being anything else; but when, time after time, I lost sight of a slug beneath my very eyes, and had often no other means of finding it again than by touching the various small "stones" with my knife till I found a soft

one, the conviction forced itself upon me that here was a case of true protection, and that what deceived me would also

Photo: H. W. Shepherd Walwyn, Esq., F.Z.S., F.E.S.

FIG. 2.—THE LAPPET MOTH ON A TWIG.

The hanging moth—to he left—has copied with considerable faithfulness both the colour and veining of the leaves on the right.

probably sometimes deceive the birds and other animals that feed upon slugs. In the tropical forests I have often had, in the same way, to resort to the sense of touch to supplement that of sight, in distinguishing between the Phasmidæ or "stick insects" and real pieces of stick; and as in this case it is universally admitted that the resemblance is a protection to the insects, since it saves them from the attacks of the numerous tropical insectivorous birds, we may well believe that our familiar slugs are similarly protected from the thrushes and other birds which feed upon them.

We will now consider some other cases of protection by colour among animals of our own country, before proceeding to those more wonderful developments which occur chiefly in tropical lands. Every collector of beetles must have observed how many of our *Curculionidæ*, or weevils, are brown or speckled, and also that they have the habit, on being touched or alarmed, of falling down on the ground, drawing in their legs and antennæ, and there becoming indistinguishable from small lumps of earth or stones. Others, however, which are found constantly on nettles and herbage, are beautifully green, and these usually run or fly away when alarmed. A curious little beetle, *Onthophilus sulcatus*, is brown and furrowed, so as exactly to resemble the seed of some umbelliferous plant. The beautiful Musk-beetle, which usually rests upon the leaves of willows, is green; while the Saperdas and Rhagiums, which frequent timber or posts, are invariably brown or yellowish. It is, however, among our moths, which are at once more conspicuous and more defenceless, that the best examples of protective colouring in this country are to be found. The beautiful green *Agriopis aprilina* and the dusky *Acronycta psi* rest during the day on the trunks of trees, and are often completely concealed by their resemblance to the green and grey lichens which surround them.

The Lappet moth, although a large and

Photo: H. W. Shepherd Walwyn, Esq., F.Z.S., F.E.S.

FIG. 3.—ONE OF THE "STICK" CATERPILLARS AT REST UPON AN APPLE TWIG.

This caterpillar will remain in this position for hours at a time.

beautiful insect, is comparatively inconspicuous, owing to the peculiar position which it assumes when it is at rest—for

the wings, which are of a rich brown colour, are deeply scalloped and indented round the edges so as to resemble the dead leaves among which it often rests after emerging from the chrysalis. The moth—which may be seen on the left of the illustration (Fig. 2)—folds its wings and lets them hang down in a manner admirably calculated to increase the resemblance, and the illusion is further strengthened by the presence of a beak-like protuberance upon the head of the moth, in imitation of the stalk of the leaf.

The Buff-tip moth (*Pygæra bucephala*) so contracts its wings that it looks exactly like a thick piece of broken stick, the yellow patch at the extremity of the wings giving the appearance of the freshly broken end. This is a case which well illustrates how impossible it is to decide from the appearance of a specimen in a cabinet whether the colours of an animal are or are not protective, for no one would imagine that this handsome and conspicuously coloured moth could ever deceptively resemble a bit of dead stick, and so obtain protection from its enemies (Fig. 7).

Some of the most striking instances of protective resemblance are to be found in these "Stick" caterpillars. One of them is portrayed in Fig. 3 standing erect in its characteristic attitude upon an apple twig, from which it has already demolished all the leaves. On the back of the caterpillar several small protuberances are noticeable, and these are the exact counterpart of those to be found upon the twig of its food-plant. This remarkable deception is rendered the more complete by the fact that the caterpillar folds his front legs together and sticks them out at right angles to his body in imitation of another protuberance. The caterpillar will remain motionless for hours together in this position, and it is often necessary, even for an expert, to actually touch the object before he can distinguish whether it is a caterpillar or a twig. Some such protection is very necessary to ensure immunity from attack, as the caterpillar is a large object, and a much-prized mouthful in the eyes of many birds.

Photo: H. W. Shepherd Walwyn, Esq., F.Z.S., F.L.S.

FIG. 4.—ORANGE-TIP BUTTERFLIES ON HEMLOCK.

Although the Orange-tip butterfly (Fig. 4) has—as its name implies—a brilliant patch of orange colour at the tip of each of its upper wings, the under-sides of the lower wings are delicately mottled with shades of yellowish-green and pure white. The object of this distinction is obvious when we notice that the butterfly, when at rest, folds its upper wings down inside the lower ones, thus practically hiding them from view. It usually passes the night upon a flower-head of its favourite field parsley or wild chervil, and at once shuts its

wings; the only part of it which remains visible is a perfect imitation of the tiny green-white flowers of the plant. The force of this deception will be brought home in a striking manner to anyone who watches one of these brilliant little butterflies on the wing, and then entirely loses sight of him, although he be perhaps only two or three feet away; while the next moment he will reappear from under the observer's very nose, and continue his flight as bright and lively as ever.

Fig. 5 shows two chrysalides of the "Purple Emperor" butterfly, which are fastened to a twig of the sallow bush, upon which the caterpillar feeds. The general contour of the chrysalis is very similar to that of the leaf, and its pale colour renders it difficult to distinguish from the silvery under-surface of the leaf.

It is a very common thing in the tropics to find beetles and moths which resemble birds' droppings, and the same occurs in this country; for Mr. A. Sidgwick, in a paper read before the Rugby School Natural History Society, says: "I have myself more than once mistaken *Cilix compressa*, a little white-and-grey moth, for a piece of bird's dung dropped upon a leaf, and *vice versâ*, the dung for the moth. Two other moths, *Bryophila glandifera* and *B. perla*, mimic the appearance of the mortar walls on which they rest; and in Switzerland I amused myself for some time in watching a moth, probably *Larentia tripunctaria*, fluttering about close to me, and then alighting on a wall of the stone of the district, which it so exactly matched as to be quite invisible a couple of yards off."

It has also been noticed that the general tints of the moths which are on the wing in autumn and winter correspond to the prevailing hues of nature at those seasons. The Rev. Joseph Greene states that the great majority of the autumnal moths are of various shades of yellow and brown, like those of the autumnal foliage; while the winter moths of the genera *Cheimatobia* and *Hybernia* are of grey and silvery tints.

It is among the caterpillars, however, that protective colouring is most general and conspicuous. An immense number of these creatures are green, corresponding with the tints of the leaves on which they feed, or brown when they rest on bark or twigs; while, as already described, a large number of the larvæ of the Geometridæ or Loopers have the habit of sticking themselves out rigidly like sticks, which they exactly resemble in shape as well as in colour. Everyone knows, however, that there are numbers of very brightly coloured caterpillars, and it may be asked how these are protected, or why the others need protection if these can do without it. The answer to this question is very instructive, and affords the most conclusive proof that the various examples of protective tints in nature really have the effect we impute to them. It has been found by repeated observation and experiment that every green and brown caterpillar, without exception, is greedily eaten by birds, and usually by frogs, lizards, and spiders, and that they endeavour to conceal themselves from these numerous enemies by feeding usually at night, while during the day they remain motionless upon leaves, twigs, or bark, of the same colour as themselves. The brightly coloured caterpillars, on the other hand, were found to be universally rejected by birds when offered to them, and, naturally, even by lizards, frogs, and spiders. None of these would touch the common spotted caterpillar of the magpie moth (*Abraxas grossulariata*), nor those of *Cucullia Verbasci*, *Callimorpha Jacobeæ*, or *Anthrocera Fipendulæ*. Sometimes the caterpillars were seized in the mouth, but always dropped again, as if in disgust at their taste. The same rule was found to apply to all the hairy or spiny caterpillars; and, what is very interesting, the habits of these creatures are correspondingly different from those of the green and brown eatable

species. They all feed during the day; they do not conceal themselves, but feed openly, as if courting observation, and secure in the knowledge of their safety from all enemies.*

This connection of gay colours and bold habits with non-edibility throws light on many other cases of bright colouring which might otherwise be adduced as opposed to the theory of protection. Thus, among our beetles we have such conspicuous creatures as the lady-birds (*Coccinellidæ*) and the "soldiers and sailors" among the Malacoderms, which are all showy and defenceless insects, never hiding themselves, or seeking concealment, or feigning death, as do so many other beetles. The reason is now found to be that, like gaudy caterpillars, they are generally unfit for food. The same explanation may be given of the conspicuous whiteness of certain moths. One of these, *Spilosoma Menthrasti*, is very common, but when given by Mr. Stainton to a brood of young turkeys among hundreds of other worthless moths after a night's "sugaring," it was always rejected, each bird in succession picking it up and then throwing it down again, as if it were too nasty to eat. The same thing has been observed with the showy butterflies forming the family *Danaidæ*. Insect-eating birds were observed by Mr. Belt in South America, catching butterflies, which they brought to their nest to feed their young; yet during half an hour they never brought one of the Danaidæ, which were flying lazily about in great numbers.

Photo: H. W. Shepherd Walwyn, Esq., F.Z.S., F.E.S.

FIG. 5.—TWO CHRYSALIDES OF THE "PURPLE EMPEROR" BUTTERFLY UPON A TWIG OF SALLOW.

But there are other modes of protection besides a nauseous taste which render concealment unnecessary. Either weapons or armour have the same effect, if they are sufficiently perfect of their kind to render it useless or dangerous for their enemies to attack them. The best examples of armed insects are the bees and wasps, and among these conspicuous colours are the rule, while the insects usually fly about and seek their food without any attempt at concealment. Others have so hard a covering, or such awkward spines, as to be practically uneatable, and among tropical insects many of these are conspicuously or gaudily coloured. One of the few examples we have of this group are the little Ruby-tail wasps (*Chrysis*) which have no stings, but have the power of rolling themselves up into a ball, which is very hard; and are so gorgeously coloured as to appear like some curious jewels. Others, again, obtain protection by extreme rapidity of flight, and by concealing themselves in holes or among flowers when at rest, and these are often brilliantly coloured, as in the case of the common Rosechafer. These few examples are merely intended to show that it is no argument against the use of protective colours in some animals, that many others have brilliant and clearly non protective hues. In those cases, the creatures have certainly some substitute

* For a full account of these interesting experiments, *see* "Contributions to the Theory of Natural Selection," 2nd ed., p 117

which enables them to live and continue their race. What this substitute is we can in some cases find out, but in many others we are too ignorant of the habits and surroundings of the species to determine whether its peculiar colours are or are not protective, or, if they are not, to determine what are the peculiar conditions which enable it to dispense with this particular kind of safeguard. An excellent example of a brilliantly coloured insect, which yet obtains protection by its colours, is afforded by the caterpillar of the Emperor moth (*Saturnia pavonia minor*). The green body adorned with pink spots is preeminently beautiful, and in most situations conspicuous; but it feeds on the common heather, and its colours then so completely harmonise with the young green shoots and small pink flowers that it is with difficulty detected.

Leaving now these familiar examples, to be found everywhere around us, let us cast a glance over a wider field, and see how the general conditions of existence, affecting many different groups of animals at once, influence their colouration for protective purposes. And first let us transport ourselves to the great deserts of the earth, and inquire what kind of animal life we find there. Canon Tristram travelled much in the Sahara, and he thus describes the characteristic colours of its animal life: "In the desert, where neither trees, brushwood, nor even undulations of the surface, afford the slightest protection against its foes, a modification of colour which shall assimilate an animal to that of the surrounding country is absolutely necessary. Hence, without exception, the upper plumage of every bird, whether lark, chat, sylvia, or sandgrouse, and also the fur of all the smaller mammals, and the skin of all the snakes and lizards, is of one uniform isabelline or sand colour." This is not a characteristic of one desert, but of all deserts. In an account of the Steppe of Erivan, in Asia Minor, it is said that "a remarkable feature of the animal inhabitants of the steppe insects and reptiles, and especially of the lizards, is the most perfect coincidence of their colouring with the colouring of the steppe." More prominent examples of this prevalent tint are such animals as the camel and the lion, which are exactly of the usual tints of sand and sandy rock.

Let us now go to the arctic regions, and we find these reddish-yellow tints entirely wanting, and instead of them pure white, or in a few cases dark-brown or black, where conspicuousness seems of more importance than concealment. All the bears of the globe are brown or black, except the polar bear, which is white. The polar hare, the snow-bunting, the snowy-owl and the jer-falcon, are also white or nearly so; while the arctic fox, the ermine, and the Alpine hare, change white in winter, as does our own Highland ptarmigan. This last bird is a fine example of protective colouring, for its summer plumage so exactly harmonises with the lichen-covered stones among which it delights to sit, that a person may walk through a flock of them without seeing a single bird; and when it changes to white in winter it is equally protected amid the snow which covers the mountains. A striking exception to the usual white covering of arctic animals is the Musk-sheep, or Musk-ox, as it is often erroneously called. This animal is of a dark-brown colour, easily seen among the snow and the ice, but the reason of this is not difficult to explain. The Musk-sheep is gregarious, and derives its protection from this habit. A solitary strayed animal would soon become the prey of the polar bears or even of the arctic foxes; it is therefore of more importance that it should see its comrades at a distance, and so be able to rejoin them, than that it should be concealed from its few enemies. Another case is that of the sable, which retains its rich brown fur throughout the

severity of a Siberian winter, but at that season it frequents trees, feeding on fruits and berries, and is so active that it catches birds among the branches. Again, the common raven is found in the extreme arctic regions, but is always black; and this is probably because it has no enemies, while, as it feeds on carrion, it does not need to be concealed from its prey. These three cases are exceedingly valuable from a theoretical point of view, for they prove the incorrectness of a common notion that animals change to white in the arctic regions either from the direct effect of cold, or from some influence of the white reflections from the snow; and they teach us that only those animals become white to whom white is useful, while those which either do not require protection or to whom dark colours are actually beneficial, remain totally unaffected. The cause of change must therefore be sought, not in the direct action of external conditions, but in the same general laws of variation and selection which have modified all the other characters of animals in the way most beneficial to them.

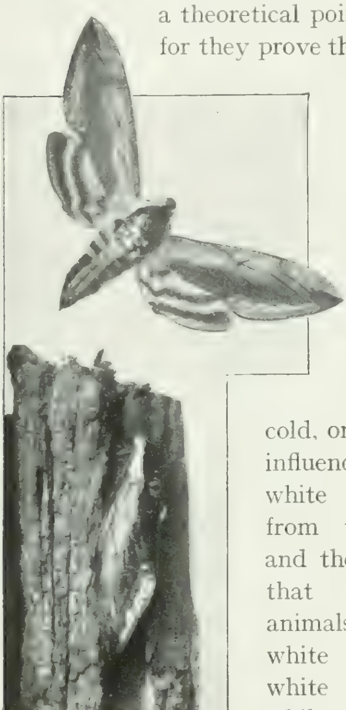


FIG. 6.—*SPHINX LIGUSTRI*, FLYING AND RESTING.

Nocturnal animals offer equally good examples of protective colouring. Mice, rats, bats, and moles are all of dusky or blackish hues, and it is therefore very difficult to see them at night, when alone they move about; while during the day they conceal themselves in holes or underground. When concealment by day as well as by night is required, as in the case of owls and goatsuckers, we find dusky, mottled tints, assimilating with bark or earth during the day, and not very conspicuous at night. In some few cases nocturnal animals are conspicuous, a striking example of which is the North American skunk, which has much white about it and a large white tail, which it carries erect in the most conspicuous manner possible. But the horrible odour emitted by this animal makes it universally dreaded, and its erected white tail is thus a signal-flag to all carnivorous animals not to attack it—a parallel case, in fact, to the white moth, which we have already seen was rejected by birds which eat so many other moths. Both are good instances of *warning* colours.

Equally striking as a proof that colour is largely protective is the fact that nowhere but among the evergreen forests of the tropical and sub-tropical zones do we meet with birds the ground-colour of whose plumage is green. Parrots, which are confined to such countries, are generally green, with small patches of vivid colours. In the Eastern tropical islands many pigeons are as green as parrots, and there are numbers of other groups which are of the same colour. Such are the barbets, a family of fruit-eating birds, especially abundant in tropical Asia; the green bulbuls (*Phyllornithidæ*); the Bee-eaters; the Turacos of tropical Africa; and the little White-eyes (*Zosterops*) of the Eastern tropics. These all frequent thick foliage, with which their colours so exactly harmonise that it is most difficult to detect them.

Contrast these with the ordinary colouring of the birds of the region of deciduous trees, of which our own country is a fair example. Here anything approaching a pure green is unknown, while brown or

olive is the almost universal body-colour of the plumage. This is the tint which is least conspicuous among the leafless trees and bushes, which prevail for so large a part of the year, when the need of protection is greatest, there being then no sheltering leafy screen.

Among reptiles these protective tints are very apparent. Our lizards and snakes are all more or less brown or olive tinged, while in the tropics they are often of a vivid green, exactly corresponding to the vegetation they dwell among. The curious geckos—flat lizards with dilated toes, which cling to the trunks of trees or to rocks—are often finely marbled with green and grey, so as exactly to resemble the lichen-covered surface on which they cling. Some arboreal snakes of the genus *Dipsas* are, however, nocturnal; and these, like all other nocturnal animals which require to be concealed, are of dusky colours, being of various shades of black, brown, and olive.

Many fishes present clear examples of protective colouring. Such as rest on the bottom, like the flounder, skate, sole, or miller's thumb, are invariably of the colour of the bottom, and often singularly speckled, so as to resemble sand or gravel. Those that swim near the surface of the water are almost always dark bluish or greenish above, and white beneath, colours which evidently tend to their concealment from enemies in the air above them or in the water below. The brilliantly coloured fishes from warm seas are many of them well concealed when surrounded by the brilliant seaweeds, corals, sea-anemones, and other marine animals, which make the sea bottom sometimes resemble a fantastic flower-garden. The pipe-fish and sea-horses (*Hippocampus*) are excellent examples of this style of colouring. Some of them are greenish, resembling floating seaweed; but in Australia there is a large species which is covered with curious leafy appendages, all of a brilliant red colour, and this lives among red seaweed, and is then perfectly concealed.

It is, however, among tropical insects that the most perfect and wonderful cases of protection by colour and marking are to be found, and a very few examples of these must now be given. The best known and most celebrated are the leaf-insects, of the genus *Phyllium* — curious large insects whose wings and wing-covers are broad and flat, shaped and veined exactly like leaves, while their legs, head, and thorax have all flat dilatations; and the whole being of the exact green tint of the foliage of the plant they live on, it is actually impossible to detect them when they are not in motion. The walking-stick insects, or spectres, are equally curious. These are slender, cylindrical insects, often nearly a foot long, and of the exact colour of pieces of greenish or brown sticks. If they have wings, these fold up closely, and are concealed under wing-covers of the same stick-like appearance; while the head and legs are so shaped and jointed as either to fit closely on to the stick-like body, or to appear like branched twigs. These creatures hang about shrubs in the forests, and can seldom be distinguished from small twigs and branches which have fallen from the trees overhead. They remain quite motionless during the day, and feed at night; and they hang anyhow across the foliage, holding on by two or three of their legs only, while the others are closely fitted to the body, thus imparting that asymmetrical appearance which belongs to accidentally broken twigs. A few of the species are still further protected by curious green, leafy excrescences all over the body, so as to look exactly like a piece of dead twig overgrown with a delicate moss. Such a one was brought to me in Borneo by a Dyak, who assured me that moss had grown over the insect while alive; it was only by very close examination that it could be discovered that the supposed moss was

really part of the integument of the insect.

Even among butterflies, whose gay colours seem only adapted to render them conspicuous, there are equally wonderful examples of protective marking.

Much more wonderful, however, and perhaps the most wonderful of all imitative insects, is the leaf-butterfly of India (*Kallima inachis, see* coloured plate). This is a rather large and handsome butterfly, of a deep bluish colour, with a broad orange band across the wings. It is thus sufficiently conspicuous; but it flies very quickly, and in a zigzag manner, so as to be caught with great difficulty. It is when at rest that it requires protection, and this it obtains by its colour and markings on the under surface, and by its peculiar habits. The upper wings have an acute, lengthened apex, which is exactly the shape of the tip of the leaf of many tropical trees and shrubs, while the hind wings are produced into a short, narrow tail, which well represents the stalk of a leaf. Between these points runs a dark curved line, representing the mid-rib, and from this radiate a few oblique markings for the veins of the leaf. The colour of the under side of the wings closely imitates that of dead leaves, but it varies almost infinitely through shades of bright yellow, reddish, ochre, brown, and ashy, just as leaves vary in their different stages of decay.

FIG. 7.—SOME REMARKABLE INSTANCES OF PROTECTIVE COLOURING.

1A. *Buff-tip moth flying;* 1B, *the same at rest.*
2A, 2B. *Catscala electa, flying and at rest.*
3A, 3B. *Prilura monacha.*
4A, 4B, 5A, 5B. *Male and female of Dichonia aprilina.*

Even more remarkable is the manner in which the diseases and decay of leaves are represented by powdered dots and blotches, often gathered into little groups, so as to imitate in a most marvellous way the various fungi which attack dying leaves. But to render the disguise effective, it is necessary that the insect should assume the position of a leaf, and this it

does most perfectly. It always settles on an upright twig or branch, holding on by its fore-legs, while its body (concealed between the lower margins of the wings) rests against the stem which the extremity of the tail, representing the stalk, just touches. The head and antennæ are concealed between the front margins of the wings, and thus nothing is seen at a little distance but what appears to be a dead leaf still attached to the branch. Yet, further, the creature seems to have an instinct which leads it to prefer to rest among dead or decaying leaves, which are often very persistent on bushes in the tropical forests; and this combination of form, colour, marking, habit, and instinct produces a degree of concealment which is perfectly startling. You see this gay butterfly careering along a forest path, and suddenly rest upon a shrub not three yards from you. Approaching carefully, you look for it in vain, and you may often have to touch the branches before it will dart out from under your very eyes. Again you follow it, and mark the very branch on which it has seemed to rest; but in vain you creep forward, and scan minutely every twig and leaf. You see nothing but foliage—some green, some brown, and decaying—till the insect again starts forth, and you find that you have been actually gazing upon it without being able to see any difference between it and the surrounding leaves. After repeated experiences of this kind, and knowing exactly what to look for, you are able sometimes to detect it in repose, and are then more than ever amazed at the completeness of the deception, and at the same time profoundly impressed with the protection that must be afforded by this wonderful disguise—a protection whose effect is seen in the wide range and extreme abundance of the species.

In this case, and in that of the moss-covered stick-insect, we see the utmost perfection of imitative colouring; and we can only understand how this has been produced, by always keeping in mind the very much more numerous cases of slight or partial protection by colour or marking. We can only now briefly indicate some of the steps by which such protection is brought about.

None of the characters of animals is more variable than are their colours, though this may appear doubtful when we look at the constant tints and markings of so many animals in a state of nature. There is, however, good reason to believe that where the tint of each animal is useful to the species, all important deviations from it soon die out. Certain it is that almost every domesticated animal varies in colour, and these varieties, not being hurtful as in a state of nature, are increased and multiplied without end. Now, if we suppose an animal to suffer from being too conspicuous, any variation of colour or marking tending to make it less conspicuous will give it a better chance of life; and as offspring tend to be like their parents, these less conspicuous varieties will often leave successors similarly endowed; but these again varying, some among them will be still more protected. Thus the protective tints will tend to become more and more perfect in each succeeding generation, till their enemies, finding the pursuit too difficult, will confine their attention chiefly to other species. Then there will be no more change till some new enemy appears, when a further advance may take place, till the protection becomes sufficiently perfect to place our supposed animal in a slightly better position than its neighbours.

It has been a difficulty to many persons to understand how such variations could explain the curious cases of the Alpine hare, the ptarmigan, and many other animals which become white in winter only, when the ground is covered with snow and white serves as a protection. It has, however, been observed that a slight

seasonal change takes place in many animals. Thus, in Siberia, the wolf, the horse, the cow, the roe, elk, reindeer, and two kinds of antelope, all become paler in colour during winter. Now, if either of these species migrated northward, till it came to inhabit a country where the winter snow remained on the ground for half the year, varieties in which the seasonal change was more and more pronounced would have an advantage, and thus, in the course of many generations, an animal might be produced which changed colour as completely as do the arctic fox or the ptarmigan.

We must now conclude this very brief outline of one of the most curious chapters in natural history. We have shown how varied and how widespread are protective colours among animals; and if we add to these the cases in which conspicuous colours are useful, sometimes to warn enemies from such as are distasteful or are possessed of dangerous weapons, at other times to aid wandering species to recognise their companions or to find their mates, we shall become satisfied that we have a clue to much of the varied colouration and singular markings throughout the animal kingdom, which at first sight seem to have no purpose but to impart variety and beauty.

FIG. 8.—THE PROTECTED GRASSHOPPER *(MACROPODA DENTATA)*.
It mimics exactly the colour of the dead leaves which it chooses for its resting place.

THE ICE-PLOUGH.

IT is autumn, and we are sitting on the hill-slope overlooking a Highland glen. It is one of those deep and wildly-romantic valleys that run seaward along the western shores of Scotland, to terminate in a deep loch, inlet, or fjord, which is to all intents and purposes the exact counterpart of the glen we have been travelling through, except that, where in the loch there is sea, in the glen there is land. The scene has been painted a hundred times. The misty morning clouds that have hung over the hills since dawn are now lifting up, and opening out the view seaward and landward. Westward, there is the loch, with its sunlit surface, and its white sails, the full extent of it concealed by the wild heathery capes, round which the fog still hangs, grey and ghostlike, as if loth to leave a scene so peculiarly in keeping with it. Out of the mist comes the cry of the sea-mews, mingled with the whir of the grouse which are flushed from the heather at our feet; while afar we can hear the distant echo of the waterfall ceaselessly splashing into the sea. Landward, the scene is wildly peaceful. The eye meets only mountain after mountain, the highest beginning to be tipped with the early snow, while the fading heather flowers give a reddish-brown aspect to the surface. A few cotters' thatched huts smoke down in the valley; a few sheep, or long-horned, shaggy Highland cattle, graze here and there. But beyond this the land is yet in a state of nature. For all the signs of man and his works around us, we might be in some Rocky Mountain valley, or looking on a scene in the Scandinavian Nordland. But we are at present studying the landscape, not from the painter's or the poet's point of view. Pleasant no doubt it is—

> "To roam at large among unpeopled glens
> And mountainous retirements, only trod
> By devious footsteps; regions consecrate
> By oldest time; and while the mists
> Flying, and rainy vapours, call out shapes
> And phantoms from the crags and solid earth;
> . . . . . and while the streams
> Descending from the region of the clouds,
> And starting from the hollows of the earth,
> More multitudinous every moment, rend
> Their way before them. What a joy to roam
> An equal among mightiest energies."*

It is our business, however, to analyse that scenery—to shut our eyes for the time being to the harmonious whole, and to investigate the elements of which it is composed. Now, in doing so, we are at once struck by the smooth, shaven, or rounded aspect of many of the rocks. Rain, wind, rivers, and weather in every form, have been ceaselessly at work moulding the mountains at their will. The rocks are accordingly worn in various fantastic forms, according to the facilities they give for the elements acting on them. They crumble away in sharp peaks, in rounded knobs, or in the low, stair-like appearance so characteristic of whinstone. Here, however, the mountains seem mostly composed of granite, or what for our purpose is much the same; and the surface is everywhere, especially on the lower grounds, rounded and smoothed, as if it had been subjected to the action of some great file. Scattered over the surface are blocks of rock, covered with the motley-coloured lichens, and weighing in some cases many tons. Most of these blocks have sharp edges, and seem to have undergone no rough usage save what the weather has inflicted upon them. Others, however, are rounded; their sharp

* Wordsworth: "Excursion," Book IV.

edges are worn off, so that in many instances they seem as if they had been rolled round and round until they have attained their present shape. Some of them are scattered on the hills hereabouts; in fact, we are sitting on one. But if we travel down into the glen, and stand in the bed of the "burn" or rivulet which runs through it to the loch, we shall see still more. Indeed, this stream—now so quiet as it trickles along through its almost dry bed, but which we can see, from the broad, rugged path it has worn for itself, is a wild ravager from the mountain when swollen by the melting snow of spring—seems to have cut its way through among these rounded rocks or "boulders." The whole soil is full of them, little and big, and the water which has washed away the clay now gurgles and splashes in, about, and over them.

FIG. 1.—A "PERCHED" ROCK.
Rocks which have been brought long distances by glaciers are frequently placed by the action of the ice in the most extraordinary positions.

But if we examine them further we detect something still more startling—viz. that many of them are of rock not the same as that on which they are lying, and that some of them are perched in strange positions (Fig. 1). The rounded boulders in the clay down on the banks of the burn in the glen are generally of the same rock as is found in the vicinity, or at least within a few miles. But the perched rocks on the hills around, or scattered about here and there, are, in the greater number of cases, rocks that are strange not only to the country about, but even to Scotland. Indeed, if you are a traveller, you may detect in many of them rocks which are not found nearer than Norway. This is a discovery, then: the blocks of stone are travellers, strangers to the neighbourhood, and, though naturalised, not of Scottish birth.

The next thing we observe is that all or nearly all of the round boulders are scratched or polished in certain places, as if some giant had rubbed them with a Titanic file, and thereafter applied sand-paper to the place, without, however, effacing the file-marks (Fig. 2).

The geologist must be a philosopher of the peripatetic school; his facts must not be collected from one isolated spot. Features here must be compared with features in other places, for only thus is the truth to be found. Accordingly, if we wish to ascertain anything accurate about the history of this weird-looking Highland glen, we must not be sparing of our legs. We again climb the hill, and examine the rocks around. Beyond being rounded and knoll-like here and there, we at first sight observe nothing very peculiar. But just as we are sitting on a smoother place than ordinary, we detect on the surface of the rock scratches and polishing very much the same as that which we saw on the boulders below. The scratches are, however, usually deeper—in some cases being more like the furrows made by drawing a garden rake over a

firm, soddened piece of soil than mere scratches. In other places, the surface is absolutely smoothed, and even polished, where the material acted upon is sufficiently hard to have taken this on. In other spots, the scratches are almost effaced by the action of the weather on the rock, or by the corroding action of the lichens. Now that we have once discovered these scratches, we seek eagerly around for more, and as likely as not find them plentifully and well preserved by pulling up the thin, hungry Highland turf that, in the course of ages, has accumulated over them, and protected them from Time — that *edax rerum* — rock-scratches included.

FIG. 2.—SHEEP ROCKS.
These rocks have been rounded, smoothed, and polished by the ice until at a distance they resemble resting sheep.

Generalisation in geology from a few facts is a dangerous, if seductive, pastime. Still, in this case we are right, if we conclude, after an hour or two's search, that, in this part of the country at least, most of the grooves and scratches take a determinate direction. They may occasionally cross each other, and in places look as if coarse sand-paper, in which each grain was a pebble imbedded in a board, had given the rock a rough polishing. Still, the conclusion from a study of the average is that they all go in one general direction. In this case it happens to be westward, or to the sea.

But something has caught our eye down in the glen. We apply the field-glass to it. It looks like a sheep asleep among the heather—a black one, too, albeit that breed is rather rare hereabouts. But no—it cannot be a sheep. We shout: the other sheep scamper off. We throw stones down on them, and they instantly show themselves sensible to such lithine persuasives. We roll a little boulder or two down the heathery slope, but the black sheep lying asleep among the heather—its back only appearing among the waving cotton-grass, blue-bells, and purple ling—remains motionless, though our missile rushes down the hill-side, through the boggy pastures, and splashes into the burn with a sound that gathers voice and echoes among the silent hills. If it is a sheep, it is perfectly certain that it is a deaf or a dead one. Finally we do what we ought to have done at first: we pay the black object a visit. Then we discover the secret of its silence—the mystery of its immobility. It is a large black boulder, firmly imbedded in the soil, or perhaps only a piece of the mountain rock appearing above the surface. But at a distance it certainly looks wondrously like a sheep. This is owing to the fact that it, too, is smoothed, and perhaps polished also, as if some great flood had for ages been pouring over it; or, better still, as if some more or less solid body had been squeezing and grinding it on its course down the valley; for it is clear that, whatever has been the grinding agent, it has moved seaward.

We have now learned so many facts—or

what we suppose to be facts, for in geology the last thing the man should do who has not learned to look is to "trust his own eyes"—that we had better pause and master the data, before the data master us. What, then, have we learned? Simply this:—

(1) That in and about this Highland glen there are certain rocks lying solitary, detached—not belonging to the immediate neighbourhood, and in many cases brought from a great distance.

(2) That many of the rocks are scratched, grooved, and polished as if some body capable of leaving an impression behind it had passed over them.

(3) That these markings are found on the rocks high and low; that the markings are all in one general direction, as if the body had been moving seaward.

(4) Last of all, it is evident that the markings—from those on the rocks at the top of the hill, to those on black-sheep-like rocks among the heather down below—were caused by the same agent, whatever that might have been.

These are facts: there is no getting over them. The next question is, What agent brought the rocks here from a distance? Here is a native of the glen, who has lived in it, "man and boy"—shepherd and sheep-farmer—"seven-and-sixty years come next shearing time." Perhaps he knows something about it? The reader will at once perceive, from our credulity as to the knowledge of the glensman, that, however sharp in Capel Court or in Chancery Lane, we are very ignorant of the character of Highlanders, and that our knowledge of physical geography is extremely elementary. "Oh, yes! he knows all about it"; and then, after ascertaining all about us—where we have come from, and where we are going—he enlightens us:—"A witch, who lived in the old times in Tramowhusky Strath, was carrying some chucky-stones to Glen Mutchin, and just hereabouts her apron-strings broke. Anyhow, that is what his father told him, and he had lived in the glen eighty-nine year; though old Donald M'Alpine did say how it was the stones

Photo kindly supplied by Dr. Carl Grossman, F.R.C.S.E., Liverpool.

FIG. 3.—ROCK SCRATCHES AT TRANGISVAAG, IN THE ISLAND OF SUDERO, FERROES.

that one giant threw at another that lived in Skye, that fell short here, and——"

It is evident that the worthy drover's geology is even more elementary than ours, and we endeavour to solve the problem for ourselves. What brought the stones here? Wind? That may be at once dismissed. The wind is gusty enough in the glen, but it is scarcely equal to blowing a shower of fifty-ton boulders from the Grampians, far less from Norway. Water? This is more likely. But though it might have rolled the boulders in the valley down to where they lie, it could never have tossed them upon the top of the highest hills, and perched them in all manner of peculiar places; sometimes even balancing them neatly on the points of other rocks, where they swing gently in the wind, as they have swung, to all appearances, for ages—and æons—past (Fig. 1). Moreover, there are no signs of water hereabouts. If we examine the clay on the cutting which the burn running through the glen has made for itself, we see nothing which would lead us to suppose that the clay or heterogeneous mass of stones on either bank had been subjected to the action of water; while the rocks perched high on the hills bear no signs of having been worn by either the waves or in the bed of a river, or by any kind of current rubbing against them. Besides, there is the fact of some of the blocks having been brought from over the sea. It would be absurd to suppose that rock was ever, like St. Cuthbert's stone coffin, capable of floating on the surface of water. This is reserved for monkish miracles, and we are endeavouring to exercise our reason. So there is no common ground between us and the monks, any more than there was between us and the witch-believing Highlander who was our first guide and meant to be our philosopher and friend. We "give it up." We have exhausted all the reasonable moving agents within our knowledge, and still have not explained the groovings, scratchings, and polishings on the rocks. For it is very probable that the scratchings are in some way connected with the travelled blocks, if the same agent that brought these stony voyagers here did not leave the scratched records of the fact on the rocks also. It is perfectly certain, however, that these scratches were made either before the travelled blocks of stone were deposited where they are, or about the same period; otherwise the agent that smoothed the rocks would have swept away the boulders upon them. It is therefore evident that mere guessing is a waste of time, and if the reader has already fathomed the mystery he must be considerate enough to pardon the writer for under-estimating his acuteness.

Next year we are in Switzerland, and spend some time in examining the glaciers in that country. The glaciers are great masses of land-ice, moving down from the mountains, filling up the valleys, and descending to the low grounds, until the warmth of the climate melts off the lower end, and thus counterbalances the force that causes them to move from above. This, for the present, is sufficient for our purpose; by-and-by we may have more to say about glaciers. On the surface of these glaciers we see moraines —that is, earth, gravel, and rock which have fallen on the sides of the glacier, and been carried from high up among the Alps, miles and miles on the snowy surface of the glacier, until, by the melting away of the end of the glacier, they have been stranded down among the vineyards and pastures of the lower valleys. There to this day you can see them scattered about. The very peasants recognise them as not belonging to the neighbourhood, and jocularly style them "foundlings." At the place where the end of the glacier was melted away we see a little of what was underneath it. There are masses of mud, stones, and blocks of rock, which,

owing to their having got frozen into the under surface of the glacier, have been rolled over and over in the course of its journey, until they are now more or less rounded, or at least have their sharp edges worn off. Again the guide—that omniscient being—will take us into Alpine valleys out of which, owing to a change of climate or other causes, the glaciers have long ago disappeared, only leaving their traces behind. There we see the travelled glaciers having passed over them when these ice-rivers crawled down the valley we are standing in. There are the scratchings and groovings, and, indeed, on every rock where the glacier has passed over we find the same marks, identical in every respect with those we saw on the Highland hills. We see how they have been formed. Stones and gravel have got frozen into the under surface of the glacier, and have ground the rocks over which

Photo kindly supplied by Dr. Carl Grossman, F.R.C.S.E., Liverpool.

FIG. 4.—VIEW OF AN OLD FARM, HVAMMUR, ICELAND.

A large boulder showing glacier action appears in the foreground. The mallet upon it is used for hammering dried cods' heads, which form a favourite breakfast here.

blocks and the rounded boulders; but we also observe something which strikes us as strangely familiar, and recalls a Highland scene of twelve months ago. We see the black sheep-like rocks rising, back up, above the pasture. We examine them, and find them in every respect identical with those we saw last year in the Highland glen (Fig. 2). To our astonishment we find that these rocks are known to the Swiss as *roches moutonnées*, or "sheep-rocks," and that their shape is due to old it had passed, just in the same way as if the glacier were a huge file, many miles in length, and half a mile in breadth, moving with an impetus that carried all before it. All around us we see the effects of this great file, working down the rocks and soil in that "eternal grind." From under the glacier a stream, formed chiefly of the melted snow which has fallen through the cracks in its surface, is ever flowing. This stream is milky in colour, and deposits, if allowed to settle, a fine

mud, which it holds in suspension. This mud is, in reality, composed of the rocks powdered into dust by the moving glacier.

Light is dawning upon us! We return to the Highland glen, as if we had received a revelation from our visit to the Swiss one. It is perfectly apparent that to ice must be due the boulders scattered over the hills, the "sheep-rocks" in the glen, the mass of rounded boulders on the banks of the "burn" down below, and the scratches on the rocks. But still there are some things not altogether clear yet. For instance, we cannot well understand how the perched blocks got to the top of the hills. If they had been deposited by glaciers, would they not have been down in the valleys?

Another fact is discovered by us on our second visit to this Highland glen. As we are passing through the valley we examine the banks of the stream flowing through it. On each side we see a cutting displaying the character of the soil. It is filled with rounded boulders * and bits of rock—all from a few miles around—but this is *débris*, arranged without any relation to the weight of the materials, showing that they were placed there not by the action of water. Moreover, we find in this mass stones scratched and polished, and—take it all in all—there seems strong reason to believe that it is the exact counterpart of the material we got a glimpse of under the Swiss glacier.

But lower down the valley—indeed, along the shores of the loch itself—we come upon another deposit. It is a whitish, fine-grained clay, identical with that which we have seen brick-makers using for moulding. Here there is no longer any doubt about the action of water. The clay is finely "laminated" like the leaves of a book, the heavier materials lowest, the finer uppermost. So far so good, and we might pass on; but in digging into it we disinter shells—sea-shells—of forms not unfamiliar to us. If we take them to a museum, we shall soon see that they are of species now living, but not, or rarely, in the seas round our islands. A few of the more common ones, which we have dug out of the clay along the loch-side, are shown in Fig. 5.

A further examination soon shows that they are shells now found commonly in the seas of Greenland, Spitzbergen, and other Arctic countries. These facts show—first, that at one time what is now land must have been sea-bottom; and secondly, that at that time the sea around the Scottish shores must have been colder than at present, so as to allow these Arctic shells to burrow in the mud. Still, everything is not very clear to us, though the curtain has been lifting up since that day when we sat, ignorant alike of glaciers and geology, on the boulder in Glen Mutchin. We can now see how the glaciers that once filled the Scottish glens deposited boulders in the valleys, and grooved the rocks; but yet we do not quite see the source of the rocks on the hills, nor of the beds of clay containing Arctic shells. Nor are we ever likely to know until we visit some Arctic country like Iceland or Greenland.

In the latter continental island, for example, you find the whole interior covered by one great glacier—swaddling hill and dale in one icy winding-sheet. If the traveller penetrates into the interior for a little way, he sees nothing before him but ice. There is ice north, and ice south; and if he goes far enough he will see the black coast, the few miles of uncovered land surrounding this ice-covered interior plateau, fading away behind him as the coast fades behind the voyager sailing out to sea in a ship. Into the inlets, lochs, or fjords of the coast this mighty sea of ice discharges itself in the form of icebergs. Now, these icebergs are simply the ends of the glaciers broken off

* Hence known to geologists as "boulder clay."

by being floated up by the buoyancy of the sea, and then falling off by their own weight. From the Swiss glaciers we have, of course, no icebergs, for long before the glaciers could reach the sea they would be melted by the warmth of the countries through which they would have to pass. But in these far northern latitudes it is different. There, glaciers form almost at the sea-level, and after a very brief course terminate in the sea. But otherwise the Alpine and the Arctic glaciers are identical. Each bears rocks on its surface, and each deposits them; but with the difference that, while in the Alpine glaciers the blocks and other ice freight are deposited in the valleys, where the glacier-end melts, in the Arctic ones the iceberg or broken-off end of the glacier carries them to sea, and when the berg capsizes, deposits them on the bottom. In fact, the bed of Baffin's Bay and Davis Strait must be now strewn with such blocks, imbedded in mud, and thus subjected but little, if at all, to the wearing action of the waves. From under the Arctic glacier, as from under the Alpine one, there pours the milky river. It flows, however, into the fjord, which it in time shoals up. In the mud deposited from the glacier-river the Arctic shell-fish burrow and live. Let us examine a bucket or two of this mud. To our pleasing surprise, we find it exactly the same as the old clay we saw along the Scottish loch-side, and in this clay are the same species of shells we found imbedded in that clay (Fig. 5). The very fjord itself is the counterpart of the Scottish fjord. It is curious that these inlets, as in Scotland, Norway, and North-West America, are always found on the western or moist sides of the country, where snow, the material out of which glaciers are made, is plentiful.* Moreover, they are never found out of the latitudes in which snow falls. Hence there is every reason to believe that at one time they were the beds of glaciers, and, from being mere depressions, were hollowed

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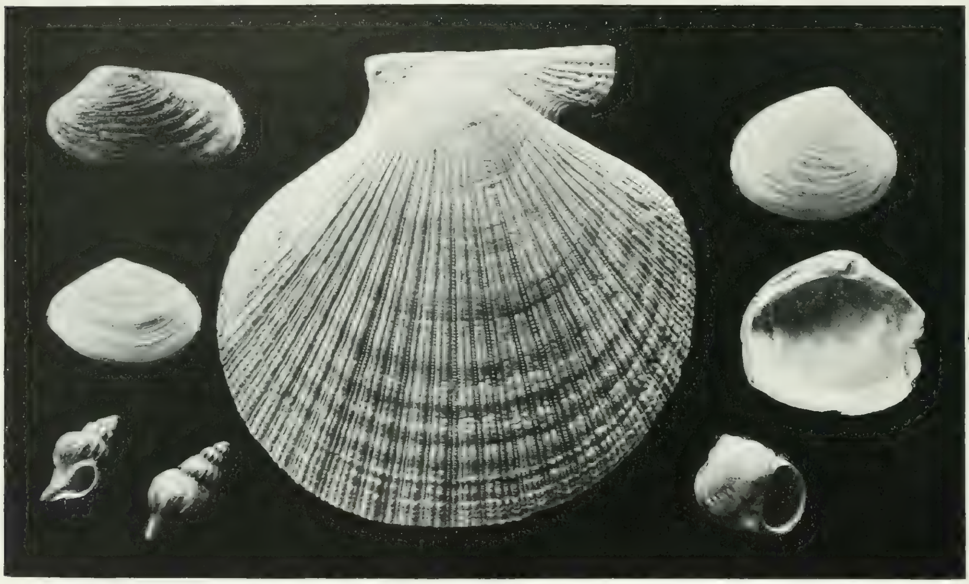


FIG. 5.—FOSSIL SHELLS OF ARCTIC SHELL-FISH FOUND IN SCOTTISH GLACIER CLAYS.

The living representatives of these molluscs are to be found to-day round the coasts of Greenland and Spitzbergen.

1. Saxicava rugosa. *2. Astarte borealis.* *3. Pecten islandicus.* *4. Trophon clathratum.* *5, Tellina calcarea (exterior of valve).* *5a. Tellina calcarea.* *6. Leda lanceolata.*

* CASSELL'S POPULAR SCIENCE, Vol. I., p. 140.

into glens on land, and fjords on sea, by the slow but sure passage of the ice-plough.

We have finished our study. We have led the reader on step by step, not concealing our difficulties as far as these are necessary to the right understanding of the subject in outline, and asking him to examine the different links in the argument. What, then, are the conclusions? These seem inevitably as follows: That at one time Scotland was swathed in ice, as Greenland is now; that her valleys were filled with huge glaciers which scored great seams upon her mountain sides, and discharged icebergs into her lochs, then chilly enough for the Arctic shells to burrow in the mud deposited from the infra-glacier rivers, as is the case in Greenland at the present day; and that floating icebergs, or perhaps an Arctic ice-floe, at intervals deposited blocks of stone, now found perched upon the hills. This, of course, presupposes that much of what is now dry land was then under the sea, and *vice versâ*. But that is a fact so familiar that it is almost unnecessary to mention so elementary a bit of knowledge. Land at the present day is rising and falling slowly. Indeed, it is the stable sea and the unstable land—not the reverse, as we have been familiarly led to believe. The period during which all this happened is known to geologists as the "glacial period." At that time the whole of the North of Europe, America, and perhaps of Asia, was covered by ice, and much of it was also under the sea. The musk-ox and the Arctic lemming lived in England, a woolly elephant roamed over the North of Asia, while the reindeer was a familiar animal as far south as France. Indeed, it is probable that at different periods in the earth's history there have been recurrent periods of cold, and that what we familiarly call the "glacial" period was the last of these periods—an epoch which, though chronologically very remote, is geologically almost immediately antecedent to man's advent on the earth. Indeed, it is by no means certain that man was not then living in Britain. There is no reason why he should not have been. He lives prosperous and even comfortable in Greenland, which is assuredly quite as icy as ever glacial Scotland was. What caused these changes in climate we cannot definitely say; and though the guesses have been numerous, and the theories many-worded, it is perhaps better to leave the reader for the time being in ignorance of them. We have seen how many remains of this glacial epoch exist in our own islands, but these are dead witnesses. Living ones are not, however, wanting. On the tops of the Scottish hills, on the summits of the Alps, the Pyrenees, the White and the Rocky Mountains—and, indeed, of all northern ranges at about the same altitude—are found what are known as "Alpine plants." These are in reality Arctic plants, remnants of the vegetation which during the chilly period grew in the vicinity of the glaciers, and which, now that they have retreated to far northern latitudes, remain behind in these bleak retreats, as witnesses of that "Great Ice Age" of which they were denizens. These living witnesses could tell us many a story of the coming and the passing of the great ice-plough, but for the present we will not attempt to take their evidence. The matter will be referred to again when we come to consider the distribution of plants.

There are few subjects on which there has been more discussion than the "glacial period," and scarcely two geologists have the same opinions on the same point. However, it is now universally held that such an epoch, or series of epochs, did exist, and that Scotland was subject to them. Some will even deny the presence of the universal ice-cap in Scotland as in Greenland, and declare that sea-ice, and icebergs with glaciers, did all the

glaciation we see on the hills. But these gentlemen reason from observations of an isolated and local character. Too much may have been made of the "theory." Some very insufficiently informed writers seem no more able to keep the "glacier theory" out of their books than Mr. Dick could keep King Charles I. out of his memorial.

At the same time, it is difficult to account for many an interesting physical feature of our earth's surface as we know it to-day without calling to mind the resistless advance of "the ice-plough."

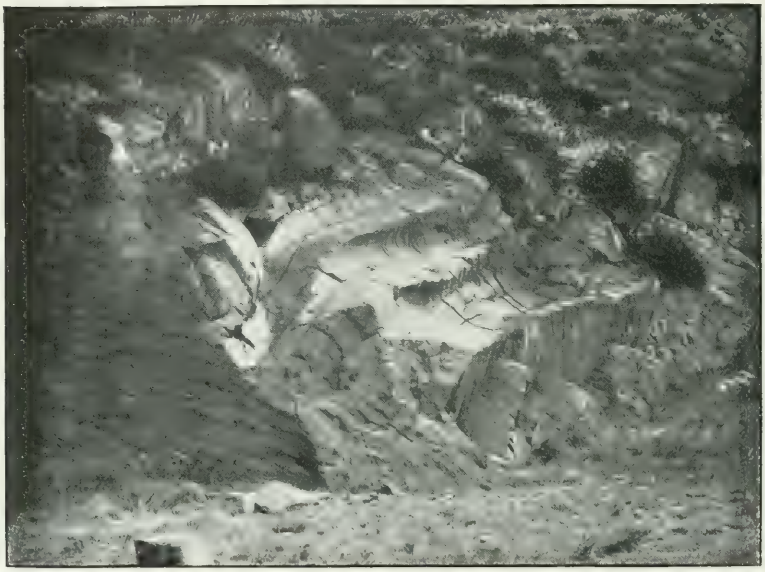


FIG. 6.—THE MARKS OF THE ICE-PLOUGH ON THE ROCKS BEHIND BARMOUTH IN NORTH WALES.

LIQUID AIR.

By T. C. HEPWORTH.

HUMAN curiosity is always excited by the marvellous, and if anything of quite a common nature be presented to us in an unaccustomed form we are apt to regard it as being supernatural. We may be quite sure that if the natives of an equatorial country were confronted with a fall of snow, instead of rain, they would be terror-stricken, and would ascribe what they considered a miracle to some occult influence. When Columbus predicted that the moon would be darkened on the eve of an eclipse, he was able to so impress the hitherto unwilling inhabitants of his new-found territory that they were only too glad to do his bidding, on condition that he would make the moon once more give her light.

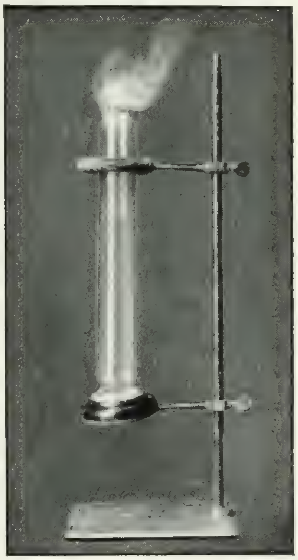


FIG. I.—A TUBE FILLED WITH LIQUID AIR HELD IN A RETORT STAND.

If a couple of hundred years ago it had been possible, in this country of ours, to produce air in a liquid state, it would have gone hard with the man who had achieved the marvel—if, indeed, his pretensions were not entirely disbelieved. For he would have made the invisible visible, and would have apparently changed its nature at the same time.

To the thoughtful person who has seen water changed to a gas, in the form of steam, or to a solid, in the form of ice, there should not be much difficulty in comprehending how air can be presented in both liquid and solid form. In both cases it is mainly a question of temperature.

There are about seventy elementary bodies known to chemistry, and three of them—hydrogen, oxygen, and nitrogen—were described in all the text-books up to about twenty years ago as "permanent gases," for they had resisted all attempts to change them to any other form. All three were subsequently reduced to the liquid state by means of cold and pressure, and the story of their conquest resolves itself into a record of devices for producing high pressure and low temperature. It will, therefore, be easily understood that the labour involved is not that of any one man, but of several earnest workers. As air is a mixture of nitrogen and oxygen, it stands to reason that if those gases can be liquefied their mixture will succumb to the same influences.

A century ago Dalton, to whom chemical science owes so much, wrote: "There can scarcely be a doubt entertained respecting the reducibility of all elastic fluids of whatever kind into liquids; and we ought not to despair of effecting it in low temperatures, and by strong pressure exerted upon the unmixed gases." In 1823 Faraday liquefied chlorine. In 1844 he again took up the same line of research, and he now had at his disposal the means of obtaining a far lower temperature, in solid carbon dioxide, in the form of snow. With this he liquefied other gases, but the so-called "permanent" ones defied all his efforts. About twenty years ago Cailletet, in Paris, and Pictet, in Geneva, independently of one another, liquefied hydrogen, oxygen, and nitrogen, and so Dalton's dream was realised—the three gases were no longer "permanent."

Our general ideas as to cold are limited in this country to about 32 degrees of frost. In Canada 40 degrees below zero is not uncommon in the winter. But what should we say to 344 degrees of frost? Liquid air is at that temperature, *i.e.* twice as far below our ordinary winter temperature as boiling water is above it. Unless precautions are taken the liquid rapidly boils away, for the heated air around is persistently trying to convert it into its normal condition, *i.e.* that of a gas. For

FIG. 2.—A BULLET LOWERED BY A STRING INTO THE "LIQUID" IS FROZEN FAST TO THE SIDE.

The glass is suspended by the string and the frozen bullet.

this reason liquid air, whilst being experimented with, is conveniently held in a glass vessel with double walls, having a space between the two in which a vacuum is preserved. Such a vessel is shown in Fig. 1, supported on a retort stand, as it would appear on a lecture table ready for demonstration.

Even under such conditions the volatile fluid rapidly boils away, and the original quantity would be reduced to perhaps one-half in about an hour's time. If, however, the inner walls of the vacuum chamber are coated with a bright deposit of silver, like a looking-glass, the access of radiant heat is also cut off, and in such a vessel air can be preserved in the liquid state for several days.

We will now consider in detail a few experiments possible with this comparatively new product of scientific research, and by the aid of these we shall be better able to understand its properties and appreciate its intense coldness. But we must be very careful in dealing with liquid air, that it is not allowed to come into contact with the skin, or a bad frostbite, which is very like a burn, will be the inevitable result. It is told of one experimenter that he had an accident of this description, and on the same day he had the misfortune to burn his hand. The ordinary burn was well in a week's time, but the air wound took three times that period to heal.

The liquid is conveniently held in its double-walled glass tube on a retort stand with a heavy foot, so that it is not easily upset, and various substances can be lowered into it by means of an attached thread. First let us take a conical leaden bullet, and lower it very gradually into the liquid. The difference in temperature between the metal and the liquid resembles that between red hot iron and water, and unless we introduce the comparatively hot bullet into the vessel very gingerly the liquid will boil over and become unmanageable. Having gradually immersed the bullet, we find a furious boiling going on, until in a minute or so the lead assumes the temperature of the liquid. We now take it out by the thread, smoking as it seems—the appearance being due to the condensation of the moist atmosphere all around it—and drop it into a tumbler half full of water at the ordinary temperature. We guide the bullet towards the side of the glass, and presently we hear a loud click. The bullet has frozen the water in its vicinity by reason of its intense cold, and the ice thus suddenly formed has frozen it so firmly to the side of the tumbler that we can lift tumbler and all by means of the

attached thread. Nor will the bullet lose its hold until it becomes warm enough to melt the icy cement (Fig. 2).

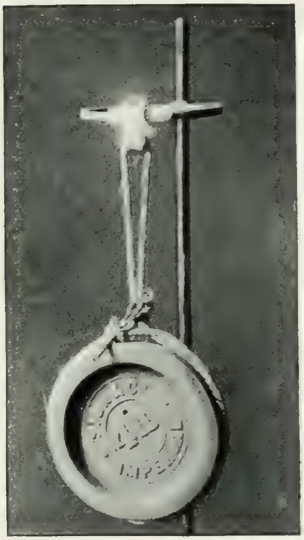


FIG. 3.—A WEIGHT SUSPENDED BY STRING AND A HOOK OF FROZEN MERCURY.

Mercury may be frozen by immersing it in the marvellously cold liquid air.

It will perhaps be maintained that it does not want an extremely low temperature to freeze water, and it may be at once granted that the experiment just detailed could be performed if the frozen bullet were at a much higher temperature than that of liquid air. So we will take a liquid, namely mercury, which does not assume the solid state until a temperature is reached of 40° below zero on Fahrenheit's thermometer, or 72° of frost. It is an awkward liquid to handle, for it runs about in nimble globules which are very difficult to catch when once they go astray. So we will fill a test-tube, about two inches long, with the metal, and by attaching a thread to the lip of the tube we can lower it into the liquid air. Again we must be careful to do this gradually, or the air will boil over. Presently, however, it settles down quietly, showing that the tube of mercury has been reduced to the same temperature as the air ; so we take it out, and hammer the mercury flat, tube and all. Of course, the thin glass is shattered—indeed, it is reduced to powder ; but it has served its purpose in holding the mercury fast during the period of solidification.

When we have hammered the metal flat, we can, by holding it with leather gloves to protect our fingers from the intense cold, bend it into the form of an S, when it can be hooked on to the retort stand, and a heavy weight hung to it (Fig. 3). The mercury has been frozen so far below its own freezing point that a minute or two will elapse before it warms up sufficiently to get liquid once more. When it begins to soften the weight falls with a crash.

One more experiment with mercury shows how the metal, solidified by cold, can be made to cement a leaden bullet to wood. A cigar-box has a centrebit hole made at one end, and this, after being bevelled on the inside, is backed up with a piece of wood glued on below, so as to

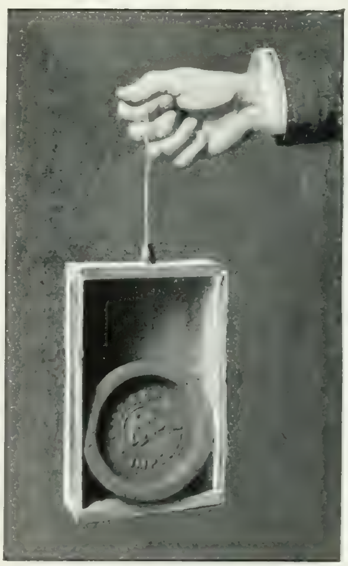


FIG. 4.—THE BULLET FROZEN TO A BOX.

The box, which contains a 7 lb. weight, may be supported by the frozen bullet and string.

make a little recess with sloping sides. This is half filled with liquid mercury, and the bullet, after being chilled as before in the liquid air, is gently dropped into the

recess. Almost immediately the mercury assumes the solid form, and the box, with a four-pound weight inside, can be held up by the string attached to the bullet (Fig. 4).

As already intimated, it is difficult to realise the intense degree of cold with which we are dealing, and in order to help us to do so we may glance at the thermometric table here given, in which the temperatures at which various liquids become solid are plainly set forth (Fig. 5).

As a convenient starting point we see at the top of the scale that water boils at $+212^\circ$ Fahr.; then we come down to the mean summer temperature, say $+55^\circ$ Fahr. Everyone knows that water freezes at $+32^\circ$ and the familiar formula "as cold as ice" expresses the common notion of a low temperature. But here we are really only at the beginning of our excursion into the ice regions of King Frost. We must get four degrees below zero before brine freezes, and forty degrees below that limit of the ordinary thermometer before mercury becomes solid. It is evident that a mercury thermometer would be useless in the arctic regions, or even in Canada, at any rate in the winter time, for the silvery column would often become solid. Happily alcohol will do as well for the purpose, and that does not freeze until a hundred degrees lower down on the scale. If, as has been stated, liquid air is at a temperature of -344°, it is certain that it will freeze alcohol, and we can easily put the matter to the test of experiment by lowering a little of that fluid in a tube into the liquid air. If we have not any absolute alcohol at hand, a little whisky or brandy will answer the purpose of demonstration. In this experiment it is best to use a conical tube, and in tying the thread to it by which it is lowered into the liquid air the end of the thread may be coaxed into the tube before the spirit is poured in. Then, when the alcohol is frozen the thread can be cut in such a manner that, while the

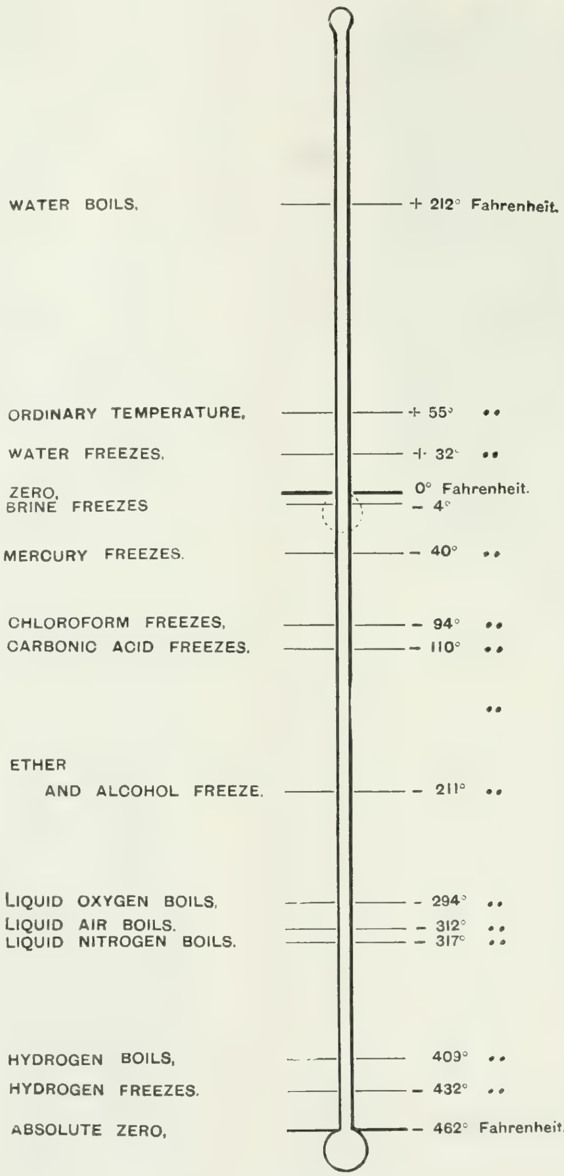


FIG. 5.—THERMOMETRIC TABLE.

Showing the temperature at which various substances congeal. Note absolute zero (− 462° Fahr.) at the bottom of the list and next to it frozen hydrogen.

FIG. 6.—WHISKY IN A NEW FORM: SOLID.
Note how the solid stick of whisky "smokes" when exposed to the external air.

glass tube is released, it is still attached to the solid spirit, which will presently slide out of its temporary case. A stick of solid whisky is a somewhat rare product, and arouses much curiosity among those who see it for the first time (Fig. 6).

Resuming our consideration of the thermometric table, we find that far below the freezing point of alcohol oxygen boils at -294°. Liquid air boils—it has been boiling ever since we began our experiments, and by this time about half of it has boiled away—at -312°, while nitrogen boils at -317°.

As air is a mere mechanical mixture of the two gases nitrogen and oxygen, and not a chemical combination, we may imagine that the molecules of the two are quite distinct in liquid, as they are in normal, air. As a matter of fact the nitrogen boils off first, leaving at the bottom of the tube liquid oxygen—which is evidenced by a glowing piece of stick at once bursting into flame when it is plunged into the almost empty tube (Fig. 7). This, it need hardly be pointed out, is the most common and effective method of testing the presence of oxygen gas, a spent match with a spark on the end quickly bursting into flame when brought within reach of the gas. It should be noted that the test signally fails when applied to the tube of liquid air when it is full; it is only when the nitrogen has been driven off by reason of its lower boiling point (see the thermometric table) that the oxygen present is able to thus assert itself. There are yet lower temperatures represented on our scale by hydrogen in the liquid and solid states, but with these we have nothing at present to do.

The intense cold of liquid air has a strange effect upon different materials chilled by being immersed in it. For example, if we lower into it by an attached thread a French nail, say of about three inches in length, we shall find that the cold has rendered it very brittle. Ordinarily one cannot break a French nail without a tedious amount of twisting backwards and forwards; it will bend easily enough. But after being chilled in the liquid air it becomes quite as brittle as cast iron, and a sharp tap with a hammer will break it in half. The experiment must be performed smartly, for the iron as it once more warms up to the normal temperature recovers its old quality of being malleable.

A somewhat similar effect is produced upon india-rubber by the same treatment. A piece of soft rubber tubing lowered into the liquid air becomes so brittle that the least tap

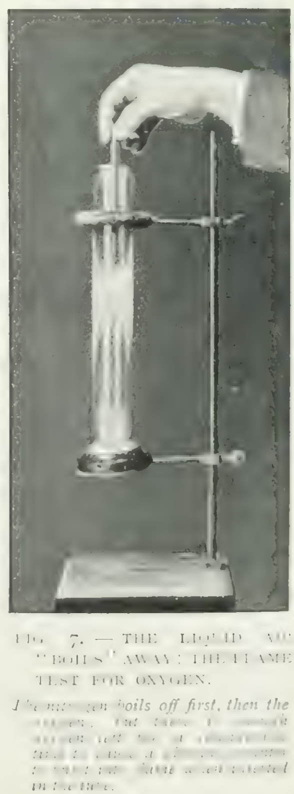


FIG. 7.—THE LIQUID AIR "BOILS" AWAY: THE FLAME TEST FOR OXYGEN.
The nitrogen boils off first, then the [illegible]

with a hammer will shiver it to pieces like so much sealing-wax. The natural elasticity of the substance returns as the chill subsides. Grapes can be frozen as hard as marbles, and flowers become as brittle as if made of glass. It is curious to see a small bunch of lilies of the valley frozen in the liquid, and afterwards crushed between two boards. The delicate flower segments are by this action reduced to an impalpable white powder in a moment of time.

Among the uses for liquid air which have been suggested in such profusion by those who have only a small acquaintance with the subject is its employment as an explosive, for use in mining operations, etc. We can test its explosive property by fastening a ball of sponge to the end of a stick, immersing it in the liquid air, and afterwards applying a flame to it. At first it refuses to ignite, but presently, when it has lost some of its nitrogen, it goes off in a puff with a sheet of flame, much in the same way that a pledget of loose gun-cotton will act. Confined in a metal tube, it would tear open that tube, just as any other explosive would do. But a moment's reflection will convince anyone that liquid air lacks all the convenience connected with gunpowder and the higher explosives now in use by miners and engineers.

Having learnt something about the properties of liquid air, we may now consider the manner of its production. The most convenient apparatus is that invented by Dr. Hampson, a photograph of which is shown at Fig. 8. It consists of a cylindrical vessel about two feet in height, in the interior of which is a closely coiled metal tube of great length. This coil is connected with an air pump worked by steam, so that a continuous supply of air is sent through the coiled pipe.

Now, it is a well-known fact that compressed air when suddenly released gives rise to a very low temperature as it expands to its original volume. The refrigerating apparatus on shipboard, by which beef and mutton from the Antipodes are brought to us in a frozen condition, depends for its efficiency on this principle, and an arctic temperature can easily be maintained in the cold chambers, provided that the compression and subsequent expansion of air are kept up by means of steam pumps. It is a curious experience to step out of the hot sunshine of a summer's day into one of these chambers, and to find its walls glistening with hoar-frost.

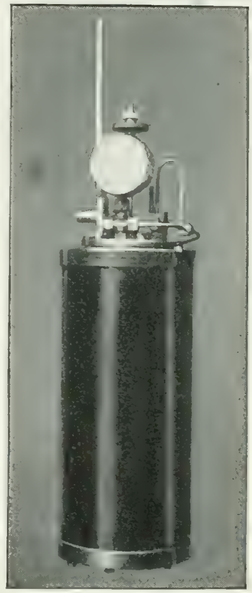


FIG. 8.—APPARATUS FOR PRODUCING LIQUID AIR.

In Dr. Hampson's apparatus the air is thus cooled, and as fast as it flows out at the bottom of the coiled pipe it is allowed to circulate about the outside of the coils. The first delivery of cold air is thus utilised to cool still further the pipe through which the second instalment comes, and by thus using the chilled air to still further chill the apparatus a degree of cold is eventually reached which reduces the last batch of air in the metal tube to the liquid condition. This beautiful piece of apparatus is to be found in all the principal physical laboratories in the world, for liquid air has now become a very valuable aid to scientific research.

Almost as soon as this apparatus was brought to perfection it was copied in America, but on a much larger scale, and liquid air was produced there in large quantities. This wholesale manufacture of the liquid was apparently not so much for scientific demonstration as for company promoting purposes, and the most absurd

and exaggerated statements were made and circulated, both in America and in this country, with regard to the wonders which would be presently achieved by the new agent. Among other wild statements, it was dubbed "the motive power of the future," and it was prophesied that it would supplant both steam and electricity as a source of energy. A Transatlantic steamer, instead of consuming from £2,000 to £3,000 worth of coal in a trip from New York to Liverpool, was to be driven by liquid air at the cost of £50, with the further advantage that the huge space occupied by the coal bunkers could be devoted to cargo. The inevitable public company was formed, and in due time came to grief.

One of the promoters of this company stated that the liquid air cost in production tenpence per gallon, which is equivalent to one penny per pound. Now, a pound of liquid air will expand to a volume of thirteen cubic feet of ordinary air, *i.e.* the air we breathe, and would, of course, do a certain amount of work in a suitable engine. But half a pound of water will expand into thirteen pounds of steam, and expanding from a smaller volume will do more work than a pound of liquid air. And half a pound of steam made in an efficient steam-raising apparatus costs only $\frac{1}{240}$ part of a penny. So that, shortly put, the vapour obtained from liquid air is more than 240 times as dear as the vapour raised from boiling water.

Another statement made was to the effect that a quart of liquid air would be sufficient to blow the rock of Gibraltar into the clouds, and that the strongest vessel that could be made of steel would not hold a pint of this wonderful liquid if hermetically sealed. That is all nonsense. Dr. Hampson has pointed out that a good steel tube three inches in diameter, with a bore of $\frac{4}{5}$ inch, properly capped at each end, would safely confine a pint of liquid air; and that if that tube were open at one end, the liquid could be held down with a closely fitting piston by eight cubic yards of Gibraltar rock.

People are so wedded to the idea that ice is typical of intense cold that it is difficult for them to conceive that liquid air is so much colder. But it can be shown experimentally that this is the case by scooping out a hollow in the top of a lump of ice, and filling that hollow with liquid air. The air boils furiously until it is dissipated as vapour.

A very beautiful experiment was shown not long ago by Professor Dewar at the Royal Institution, and was magnified on the lantern screen so that everyone in the theatre could appreciate it. The professor blew a small soap bubble and set it afloat in a bath of liquid air, the vapour from which was so intensely cold that the bubble froze into a little glass-like sphere, subsequently breaking in half, as an egg-shell might.

Some persons will doubtless be constrained to ask, "Of what good is liquid air? To what use can it be applied?" The great Faraday was asked the same question with regard to some experimental work which he happened to have in hand, and he turned to his questioner and said, "Of what use is a baby?" We do not yet know that liquid air has any particular use beyond putting at the disposal of science a means of securing an extremely low temperature. In this respect it has opened out a field of investigation which may in time lead to discoveries of a most valuable kind. When the first machines were made for obtaining cold by means of the compression and subsequent expansion of air, the thoughtless might have asked the same question, "Of what good is it?" We are able to answer that question to-day, and to point out that the introduction of the refrigerating chamber on shipboard and of the cold storage system generally have more or less benefited every one of us, by both cheapening our food supplies and placing upon our markets commodities which were once far beyond our reach

MAN, MALARIA, AND THE MOSQUITO.

By WILFRED MARK WEBB, F.L.S.

THERE is still a tendency to very much under-rate the value of scientific work. People are apt to take intricate commercial processes and even familiar mechanical contrivances for granted, forgetting that many of them have resulted from years of patient, if apparently objectless, research. Some may be ready to allow that the electric light, for instance, and the Röntgen rays are the outcome of pure experimentalising in physical science, but few yet recognise that biological investigation can confer any benefit whatever upon mankind. It is true that the individual student of life has to rest content with but little reward of a solid nature, but it must be remembered that we depend for our food supply, to mention nothing else, entirely upon living things. This supply can only be produced, and protected from harm, by a knowledge of the conditions of life, while it may be pointed out that the study of some of our own most insidious enemies has of recent years developed into the new science of bacteriology. The latter deals, as is well known, with the most minute forms of plants yet discovered; but we are also exposed to the attacks of tiny animals, and nothing, it has been advanced, could illustrate better the advantages accruing from biology than the history of the malaria parasite and its remarkable habits, or of the brilliant discoveries which led to their determination.

Photo: Dr. Logan Taylor.

FIG. I.—MALARIA-BREEDING PUDDLE: SIERRA LEONE.

Four hundred years before the Christian

era intermittent fevers, we are assured by medical men, were as well recognised and classified as they are to-day. Hippocrates, for instance, was well informed upon the matter, and stated that they were more frequent in summer and autumn in the neighbourhood of stagnant water. It was not, however, until within fourteen years of the beginning of the twentieth century that an Englishman, Major Ronald Ross, definitely traced in the mosquito the malaria parasite discovered in 1880 in human blood by the French investigator Laveran.

1a 2 3 4

FIGS. 1*a*–4.—THE MALARIAL PARASITE EARLY IN ITS CAREER.
1a, "Exotospore." 2, 3, 4, The exotospore after entry into the red blood corpuscles of man.

The parasite, which, during part of its life history, lives actually inside the red blood corpuscles of man, is a tiny unicellular animal consisting of protoplasm with a denser spot, the *nucleus*, in turn provided with a *nucleolus*. It therefore belongs to the group "Protozoa," and is placed with a number of other parasites in a class which goes by the name of "Sporozoa." There are several species of malaria parasites, each connected with a definite form of intermittent fever, and these, together with some similar parasites to which birds are subject, form the family "Hæmamœbidæ."

The members of the genus "*Hæmamœba*," which cause malaria in man, can vegetatively reproduce themselves when living in his blood, but in order that the parasites may breed and be conveyed to fresh human victims it is necessary for them to go through certain stages of development within particular species of mosquitoes. We have, therefore, one of those remarkable cases where one animal depends for its existence upon two others, and in this instance so far removed from one another in the scale of development as a two-winged insect and the two-legged "lord of creation."

Turning now, however, to the details of the story, suffice it for the present to say that the malarial parasite enters man—when he is bitten by an infected mosquito—in the form of a small motile body (the *exotospore* or *sporozoöite*—Fig. 1*a*). This is long and narrow, being pointed at each end and curved somewhat; it penetrates into the interior of a red blood corpuscle (Figs. 2, 3, and 4), and changes gradually into another form—the *amœbula* (Figs. 5–7).

Some idea of the minute size of the parasites may be obtained from the fact that 3,000 of the red corpuscles which they invade would, if laid side by side, measure but an inch. The amœbula, like the proteus animalcule (*Amœba*) of our ponds and ditches, is constantly changing its form and moving from place to place within the narrow confines of the corpuscle (Figs. 5, 6, and 7)—being now clearly visible near the surface, now deeper in

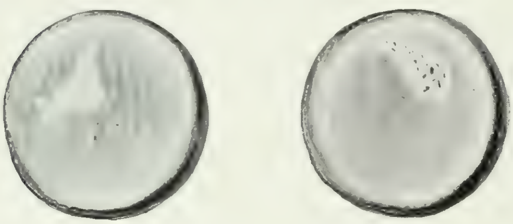
5 6 7

FIGS. 5–7.—FURTHER DEVELOPMENTS IN THE RED CORPUSCLES: THE AMŒBULA STAGE.

its substance and more obscure. From the red corpuscle the parasite obtains the nutriment it requires for its growth, and, as a result of its feeding, black granules appear in its body which are derived from the red colouring matter (*hæmoglobin*) of the former. The granules increase in number as the amœbula grows, and at last congregate together in its centre. A further change, and one no longer of a

FIGS. 8, 9, AND 10.—THE PARASITE BECOMES ROSETTE-SHAPED AND REPRODUCES ITSELF VEGETATIVELY.

The burst corpuscle is shown at Fig. 10, many spores having been liberated.



FIGS. 11 AND 12.—BEGINNING OF THE PARASITE'S DEVELOPMENT IN THE MOSQUITO: THE CRESCENT STAGE.

temporary character, now begins to take place. The nucleus of the organism breaks up, and the parasite comes to have the appearance of a rosette (Figs. 8 and 9). This is due to the general protoplasm of the cell similarly dividing, and in the end each fragment of the nucleus is surrounded by a separate portion of the former, giving rise to a number of roundish bodies (*enhæmospores*—Fig. 9), which are liberated by the bursting of the corpuscle (Fig. 10). Each "enhæmospore" enters a fresh red corpuscle (Figs. 11 and 12), and, growing at the expense of the latter (Figs. 13, 14, and 15), becomes a "*crescent.*"

If at this point blood containing "crescents" be sucked by a mosquito into its stomach, these structures will become differentiated into males and females. The former enlarge and become spherical (Figs. 16, 17, and 18), developing, in time, on their surfaces several long projections (Fig. 19). Similarly, the female "crescent" becomes a spherical *egg-cell* (Figs. 20 and 21), and, after the extrusion of a small portion of its substance (polar body—Figs. 22 and 23)—in a similar way to which this is done in the case of the eggs of higher organisms—it is ready for fertilisation. This is effected by one of the processes (*spermotozoön*), which becomes severed from the male sphere, and, being endowed with powers of locomotion, enters the substance of the egg (Fig. 24).

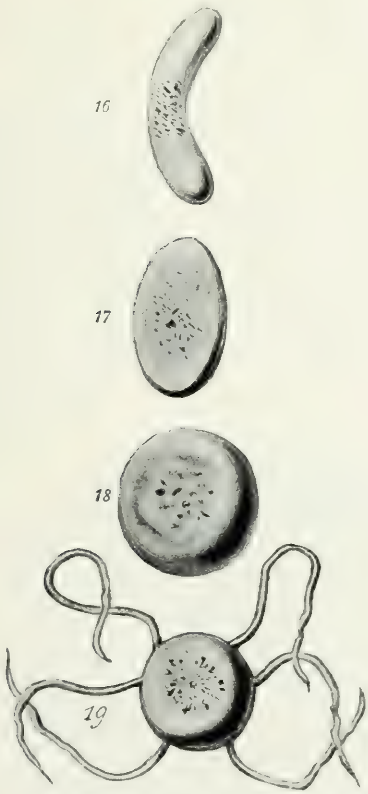
The fertilised egg takes up nourishment, and develops into an active motile *vermicule* (Fig. 25), which bores its way into the wall of the mosquito's

FIGS. 13, 14, AND 15.—THE CRESCENT CONTINUES TO GROW IN THE RED BLOOD CORPUSCLES OF THE MOSQUITO.

stomach. Here it becomes spherical once more and increases greatly in size (Figs. 26 and 27), being also pigmented and surrounded by a capsule, while its protoplasm breaks up into a number

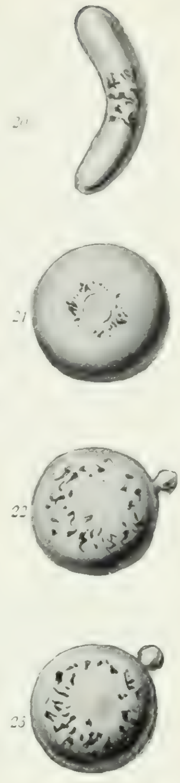
of smaller spheres — the *spore mother cells*. Each of these develops into a number of exotospores (Fig. 29), which we have already noticed, and these being set free by the bursting of the sphere find their way into various parts of the mosquito's body, including its salivary glands. Thence the introduction of the spores into the human system readily follows when the mosquito bites and moistens its mouth-parts preparatory to enjoying a meal.

It now behoves us to consider the insect which, in the language of the naturalist, acts as one of the hosts of the Hæmamœbæ,



FIGS. 16–19.—SHOWING THE DEVELOPMENT OF A MALE "CRESCENT" IN THE MOSQUITO.

and we may as well in the first place disabuse our minds of the idea that a mosquito is anything else than a gnat. It is not everyone, however, who knows what a gnat is, and there is nothing surprising in the accounts we see from time to time in the newspapers that mosquitoes have been caught in this country, for gnats abound here, and gnats are mosquitoes. What is strange, however, are the pretty little stories as to how the insects or "the germs," by which, presumably, is meant the larvæ (which, by-the-bye, live entirely in water), "came with fruit from South Africa or South America, with plants from the Continent, or in timber from Canada." Interesting, also, are the surmises as to why London should be attacked, seeing that "anyone who understands the temperament of the mosquito knows that a very necessary requisite to its existence is pure air." The fact of the matter is that most people look upon the midges that fly in flocks in the evening as gnats, so that when they



FIGS. 20–23.—THE GROWTH OF A FEMALE "CRESCENT."

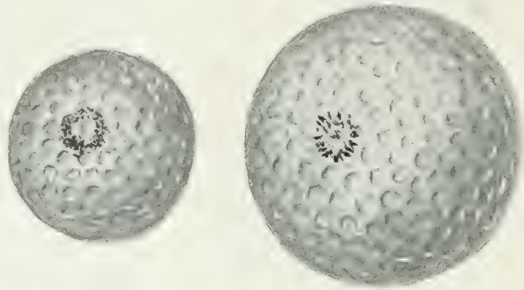
FIGS. 24 AND 25.—FERTILISATION OF THE FEMALE "CRESCENTS," WHICH NOW BECOME EACH AN "EGG CELL."

A motile "vermicule" comes from the egg cell, as seen in Fig. 25.

find a real gnat they dub it a mosquito, and think that it is not indigenous.

The mosquitoes, or gnats, however, which

carry malaria belong to a special genus known as *Anopheles*, while our ordinary grey species is a *Culex*. It is the female insects in nearly all cases (including those belonging to the first mentioned genus) which alone suck blood, and therefore play a part in the spread of disease.



FIGS. 26 AND 27.—THE "VERMICULE" BECOMES SPHERICAL AND INCREASES IN SIZE.

There are, we may say, some very clear points of distinction between *Anopheles* and *Culex*. The latter, to begin with, when at rest holds its head below the level of its body (Fig. 30), and has, therefore, a characteristic humpbacked appearance which the malaria carrier lacks (Fig. 32). Species of *Culex* also are often marked with stripes upon the abdomen, and their proboscis always makes an angle with the body, while in *Anopheles* the proboscis is practically in one straight line with the body, which is not banded. In fact, the special feature of the insect to be most dreaded is what one observer has called its "brad-awl shape." In nearly all the species of *Anopheles* there are spots along the front margin of the wings (Fig. 34), which themselves have, as a rule, a speckled appearance not to be seen in *Culex*, which seldom has spots in the position just alluded to (Fig. 33).

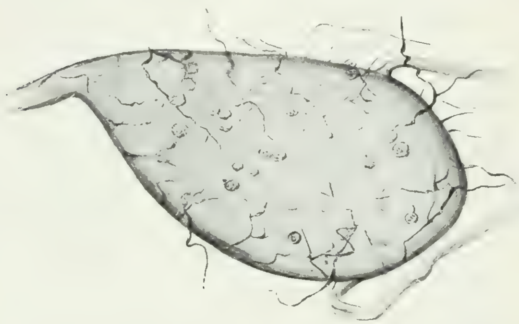


FIG. 28.—STOMACH OF MOSQUITO, SHOWING "SPHERES."
(After Daniels.)

In the case of American gnats, at least, it has been determined that the insects of the two genera can be distinguished by the note they emit when flying—that of *Anopheles* being several notes lower than the piping of *Culex*, and by no means so distinct.

The actual method by which the blood of the victim is obtained by gnats is worthy of our attention. Typically, an insect has three pairs of appendages (in reality corresponding to "limbs") connected with the mouth. There are two simple jaws or *mandibles*, a couple of double-bladed and jointed structures provided with a well-developed "palp"

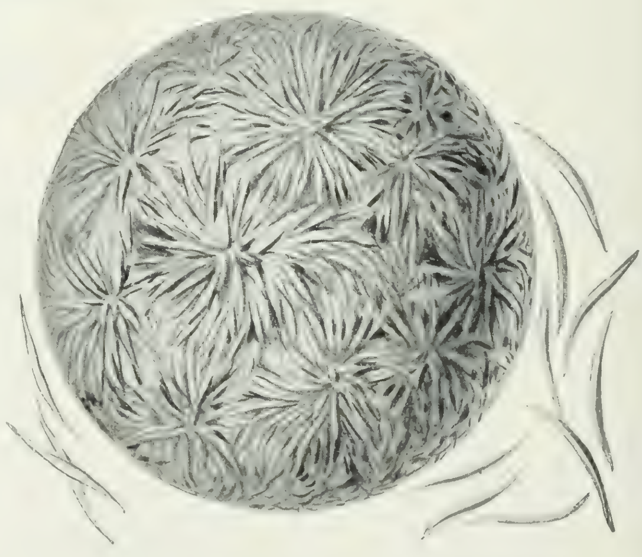


FIG. 29.—FURTHER GROWTH OF THE "SPHERE."

It ultimately produces exotospores which are shown at the side. These exotospores are now capable of infecting man with malarial fever

called the ***first maxillæ***, and a very similar pair, the ***second maxillæ***, fused together, forming what is called the "*lower lip*," and provided with shorter "palps" (Fig. 31). Oftentimes the upper part of the head is prolonged, to cover in these structures more or less, with an "upper lip." While these organs are exceedingly well adapted for manipulating and masticating solid food, it is evident that they would not be similarly useful for piercing and sucking. Hence, in the gnats, the structures described, though present, are modified in a very striking manner, well illustrating how Nature can ring the changes upon her models, in order to adapt her creatures for very varying habits and modes of life. To continue, in the gnat (Fig. 32) the "upper lip" is styliform, long, and sharply pointed; so are the mandibles and the first maxillæ—excepting that there are saw-like barbs near the ends. There is a sixth lancet in the shape of a projection (*hypopharynx*) from the inner surface of the "lower lip," which latter seems to act as a protection to the bundle of excellent piercing tools. The whole series of structures just described constitutes the proboscis of the insect.

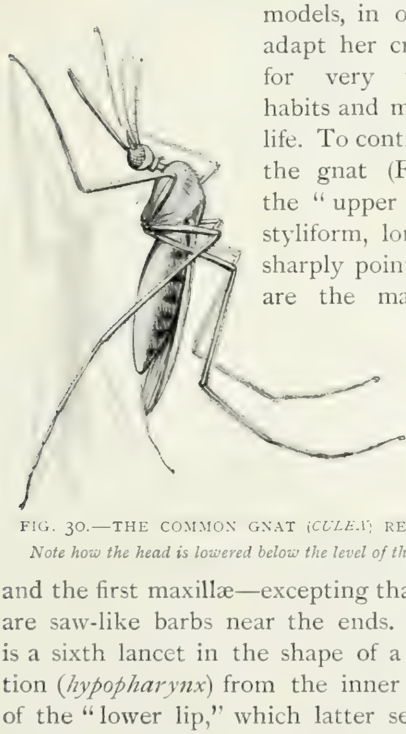


FIG. 30.—THE COMMON GNAT (*CULEX*) RESTING.
Note how the head is lowered below the level of the body.

The "hypopharynx" pierces the skin, the other stylets are inserted to enlarge the opening, and saliva is poured out, causing a freer flow of blood, which is sucked up between the series of organs.

There is an important difference between the times which the insects we are concerned with choose to carry on their feeding operations. While some species of *Culex* seek out their victims by day, those of *Anopheles* very seldom begin work before evening or even night sets in, a fact which we shall see has a very important bearing upon the contraction of malaria. Another point of great economic interest is the habitat in which the early life history of *Anopheles* is passed. The larva lives in stagnant or very slowly moving water, hence the prevalence of the adult insect and of malaria in swampy

FIG. 31.—MOUTH PARTS OF THE GNAT (*CULEX*).
(After Beecher.)

u, upper lip.
h, hypopharynx (piercing weapon).
J J, jaws.
M M, first maxillæ.
L, lower lip.
p, palp

FIG. 32.—MALARIAL MOSQUITO (*ANOPHELES*) RESTING.
Side view.

FIG. 33.—COMMON GNAT (*CULEX*).
Wings outspread.

FIG. 34.—MALARIAL MOSQUITO (*ANOPHELES*).
Wings outspread.

places. Tastes differ as to the spots chosen by the two genera with which we are concerning ourselves. While *Culex* will lay its eggs in a water-butt or in rain-water which has been caught by still smaller receptacles, *Anopheles* rarely chooses any but natural accumulations of water on the ground, though these may be nothing that can be considered above the dignity of a puddle (Fig. 35). It is said to have a preference for water well supplied with vegetation, as in the stagnant pool shown in Figs. 1 and 42.

The female *Anopheles*, unless they have had a meal of blood, will not breed and produce eggs. The latter are laid in numbers, sometimes of a hundred at a time, but each individual is separate from its neighbour (Fig. 35, C), instead of being glued together to the floating "raft" characteristic of *Culex*. The larva differs also from that of the last mentioned genus in having no breathing tube and in lying horizontally beneath the surface film of the water, instead of hanging from it at an angle. Its breathing orifices are, however, freely exposed to the air (Fig. 35, B).

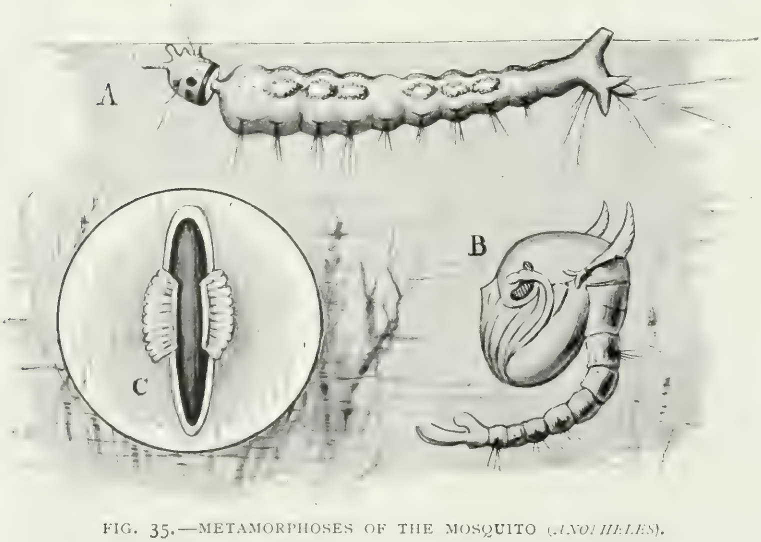


FIG. 35.—METAMORPHOSES OF THE MOSQUITO (*ANOPHELES*).
(Modified from Howard.)
A, Larva. B, Pupa. C, Egg.

There is an interesting pair of structures developed on the anterior margin of the head of the larva. These are "tufts of

slightly curled, stout, dark brown hairs, the so-called 'brushes' or 'whorl organs,' by the regularly alternating flexion and extension of which a strong current is set up, which sweeps into the cavity of the mouth the algæ - spores, diatoms, protozoa, and other minute unicellular organisms of which the food of the larva mainly consists."

Photo: Professor Celli, Rome.

FIG. 36.—ITALIAN PEASANTS: PROTECTED.

The pupa (Fig. 35 B), corresponding to the chrysalis stage of other insects, is much like that of *Culex*, but rests more uprightly in the water, though the perfect insect similarly emerges from a slit in the back.

I have already pointed out how well the Romans recognised the types of intermittent fevers, and Dr. Sambon has recently alluded to the clearness with which Aulus Cornelius Celsus characterised the quotidian, the tertian, the semi-tertian, and the simple and double quartan. Dr. Sambon further says that the description given by the Latin author of malignant tertian is so exact that, after eighteen centuries and all recent scientific investigation, we need not change one word of it. Still more remarkable, however, were the conclusions arrived at by the Romans as to the causes of malaria. Several authors, in speaking of the proper place in which to build a house in the country, point out that spots near marshes are to be avoided on account of malaria; and Varro, for instance, attributes this to minute animals which the eye cannot see, but which enter the body.

Such a striking explanation Dr. Sambon puts down, not to happy intuition, but to careful observation, saying that the old Romans undoubtedly based their opinion upon long experience, judicious analogy, and sound common-sense. The fact remains, however, that, by prodigious draining operations, malaria was banished, and stately cities flourished in spots which were, and now are, the deadliest districts in all Italy.

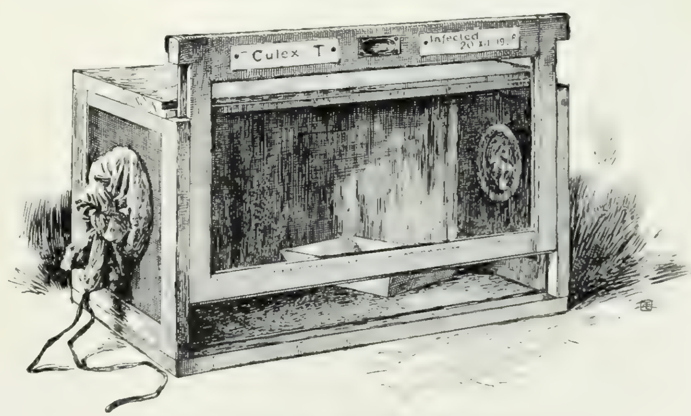


FIG. 37.—BREEDING CAGE FOR MOSQUITOES.

By permission from "The Practitioner."

The blame for malaria was not always given to swamps; chills and electrical

conditions of the atmosphere were at times considered to be its causes. The name, however, springs from the idea of poisonous emanations of the marshes, and the disease has been ascribed to oils excreted by plants, while so late as 1849 and 1879 respectively it was supposedly traced to a microscopic fungus and a definite bacillus.

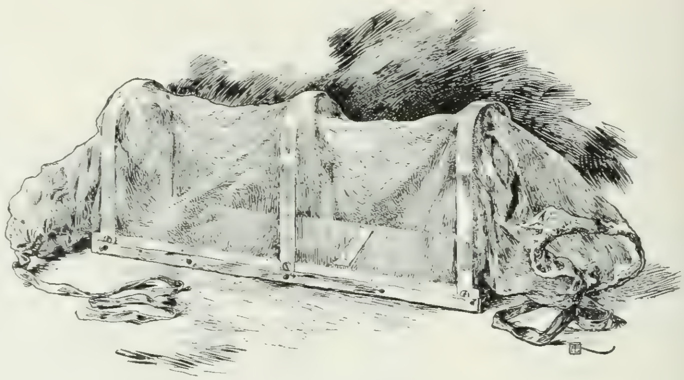


FIG. 39.—INFECTING CAGE FOR MOSQUITOES.

By permission from "The Practitioner."

In 1717 Lancisi, the physician of Pope Clement XI., was the first to look for some specific organism in the air of marshes, and paid great attention to the life history of the mosquito. In 1847, Heinrich Meckel found pigmented cells in human blood, and a number of other observers confirmed his observations of what were, of course, the *Hæmamæbæ*, though not one of them imagined that they were the cause of malaria.

Alphonse Laveran, to whom I have already alluded, when working as an army surgeon in Algeria, in 1879, began the study of malarial pigment, and soon discovered that the cells which contained it were independent organisms. In November, 1880, he was able at last to recognise actual movements, but considered that the malarial organism was a plant, and also did not determine that it lived actually inside the corpuscles. Another French surgeon named Richard made this point clear a couple of years later. In Italy, Laveran repeated his investigations, but failed for some time to shake the Italian workers from their allegiance to the bacillus theory. Marchiafava and Celli, however, came round to Laveran's opinion, and the work progressed merrily. Professor Golgi, in 1886, showed that the paroxysms of fever depended upon phases in the development of the parasites, and discovered that the various types of fever were caused by different species of parasites. He also called attention to the "crescents." Manson came to the conclusion, in 1894, that the malaria parasite in man was one stage in the life history of an organism which went through other phases outside his body. The same investigator also suggested that the mosquito, which in days of old had been credited with spreading the disease—and comparatively recently

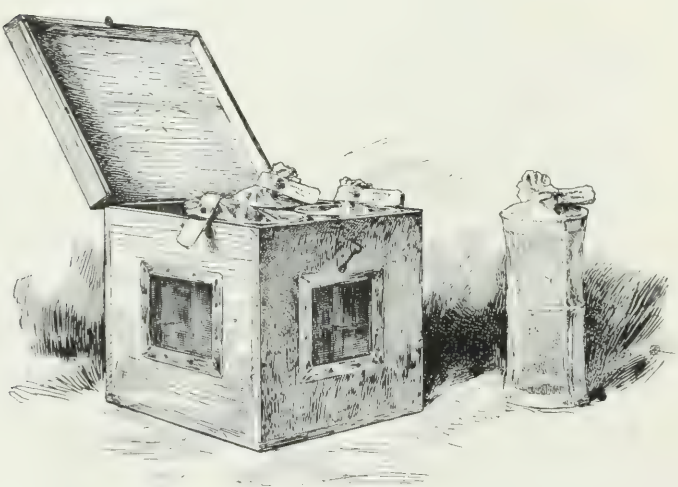


FIG. 38.—DR. SAMBON'S TRAVELLING CAGE FOR MOSQUITOES.

By permission from "The Practitioner."

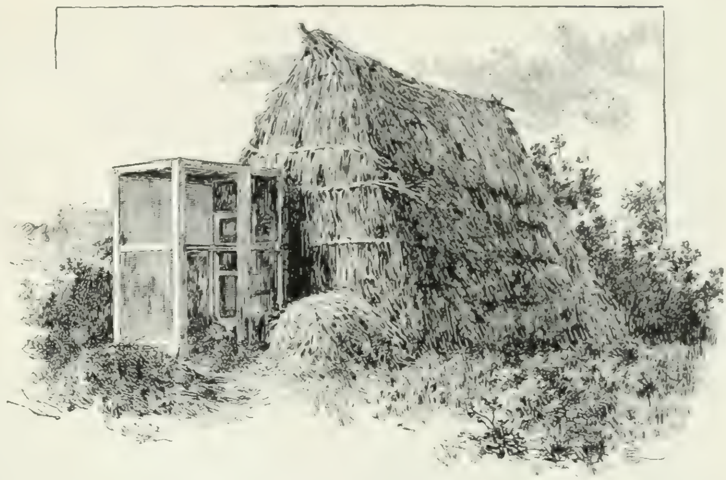


FIG. 41.—CAMPAGNA PEASANT'S REED HUT: PROTECTED FROM MOSQUITOES.
(After Celli.)
By permission from "The Practitioner."

had been shown by him to be the intermediate host in the case of another parasite—was the actual carrier of malaria. In 1895 Ross undertook to verify Manson's theory, and he began work in India, but found his task an exceedingly difficult one. To make matters worse, the authorities moved him from the station where he was investigating to another where he had little opportunity of going on with his work. In August, 1897, however, after two and a half years of failure, he found malaria parasites growing in mosquitoes belonging to the genus *Anopheles*. After this Ross completely traced the development, in the mosquito, of similar parasites affecting birds, and succeeded in infecting healthy birds by the bites of mosquitoes in July, 1898. Later on in the same year Ross's discoveries with regard to man and the mosquito were repeated and confirmed by Professors Koch and Grassi on the Continent, as well as by Doctors Bignani and Bastianelli, who succeeded in infecting healthy men by the bites of mosquitoes in Italy.

Very ingenious contrivances have been devised in connection with keeping mosquitoes in captivity with a view to experimenting (*see* Figs. 37, 38, and 39). Mr. Rees, the medical superintendent of the London School of Tropical Medicine, breeds and rears his *Anopheles* in a little cage. The insects are fed with apple or banana, as a rule, but if it is desired to increase the stock they are given a meal of blood by the insertion of an arm into the cage. The eggs are laid in a little dish, the water of which is carefully prevented from becoming foul. Mosquitoes which it is desired to infect from a patient suffering from malaria are put into a special cage with "sleeves" at the ends (Fig. 39), or they may be allowed to bite through the netting of the little travelling cages invented by Dr. Sambon for their transference from Italy to this country (Fig. 38).

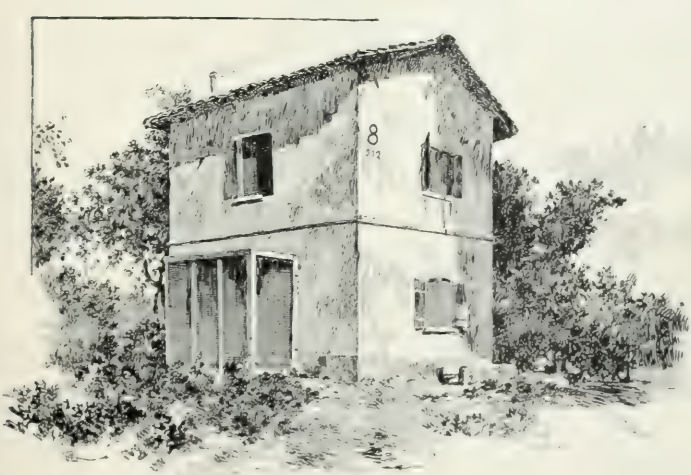


FIG. 40.—RAILWAY LABOURER'S COTTAGE: PROTECTED FROM MOSQUITOES.
(After Celli.)
By permission from "The Practitioner."

Having once pinned down the conveyance of malaria to the mosquito, the importance of the discovery in connection with preventing infection, and more, the extermination of the disease, is obvious. In the first place, while mosquitoes abound and malaria-stricken human beings are hardy, it will, of course be necessary to devise methods of avoiding the unwelcome attention of the insects. Advantage has been taken of the fact that *Anopheles* bite, as a rule, only in the evening or at night. Doctors Sambon and Low spent an entire season in one of the worst parts of Italy, and by merely keeping within their mosquito-proof house from sunset to sunrise they, their companions, and their servants remained the whole time without anyone contracting the disease, while of the population of the place no one escaped.

Celli, in 1899 and 1900, carried out a number of experiments with labourers on the railway and with peasants, and protected their cottages and reed huts (Figs. 40 and 41). In one case of fifty-two persons residing in the mosquito-proof dwellings not one got fever, while of fifty-one in unprotected houses only seven escaped. The test with children is the most noteworthy—while all (thirty-six) in the first case escaped the disease, all (twenty-nine) in the second contracted it.

In the second place, malaria-stricken patients should be similarly protected, in order that mosquitoes may not have access to them and carry on the disease to other human beings, and by the use of quinine the malaria parasite may be prevented from reaching the infective stage.

When all is said and done, however, the best method to adopt in malaria-infested countries is to get rid of the mosquito. Twice Major Ross has been on an expedition to Sierra Leone from the Liverpool School of Tropical Medicine, and experiments have been made in various directions. The draining of swamps and the filling up of small pools and puddles, so that there is no water in which the larvæ may come to perfection, is the most obvious method of procedure. Empedocles of Agrigentum had a coin struck in his honour by Eclinus, because he delivered his city from malaria by getting rid of the surrounding marshes. Ague has practically left our eastern counties now that proper drainage is carried out, and many similar instances might easily be advanced. By preventing, also, prolonged floodings of land in tropical countries mosquitoes might often be deterred from reproducing their species, while a simple way to destroy their larvæ in pools without draining them is to keep a film of petroleum on the surface of the water, so that the larvæ are not able to reach the air, and therefore cannot breathe. The way is now open, and if it be followed malaria should soon be a thing of the past.

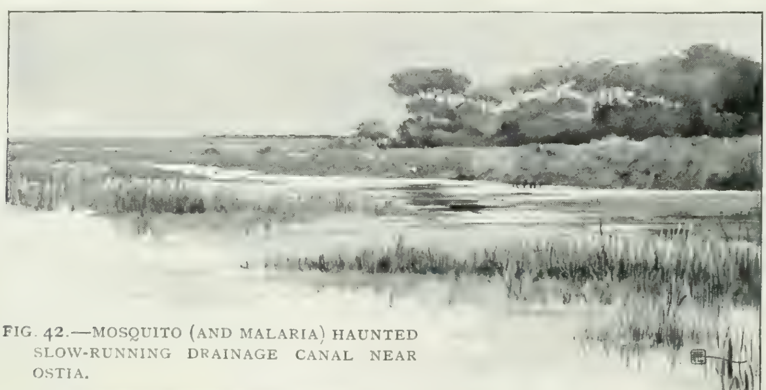


FIG. 42.—MOSQUITO (AND MALARIA) HAUNTED SLOW-RUNNING DRAINAGE CANAL NEAR OSTIA.

By permission from "The Practitioner."

THE SCIENCE OF ANIMATOGRAPHY.

HOW "LIVING PICTURES" ARE MADE.

By JOHN MUNRO.

LIKE nearly all great inventions, the apparatus for producing what are called "living pictures," or "animated photographs," reproducing the movements and having a semblance of life, is a gradual development from an original idea by the improvements of successive inventors. Its fundamental principle is familiar to us from childhood in the sport of whirling a burning stick in the hand until the red-hot end seems a fiery hoop. This illusion is due, as many are aware, to what is called "persistence of vision," or the fact that an image or picture of an object seen remains for a certain time—about one-fifteenth to one-tenth of a second—on the retina of the eye. The glowing end of the firebrand forms different images on the retina as it is moved, but these follow one another so quickly that they are blended into one, and appear as a ring of light. In like manner, if, whilst looking at an object we wink some ten or fifteen times a second, that object will be visible all the time. This phenomenon has long been known. It is mentioned in the poem of Lucretius on the nature of things, which dates before the Christian era, and in Ptolemy's "Optics" (about 130 A.D.), and an experiment with a revolving disc is based upon it.

Phot.: R. W. Paul.

FIG. 1.—ANIMATOGRAPH OPERATOR TAKING PHOTOGRAPHS FOR "LIVING PICTURES."

The earlier experiments were made with the same object seen in different places, but in 1826 Dr. Paris invented a *Thaumatoscope*, by which two objects were seen in the same place at once. A card, bearing on one side the picture of a cage and on the other of a bird, was revolved so fast that the bird appeared in the cage.

Another step was taken in 1832 by Plateau, who in his *Phenakistoscope*

presented various postures of the same object to the eye in rapid succession. Plateau, in 1849 also suggested the use of photography in making the pictures required for his apparatus; and in 1853 Prokesch devised a magic lantern for projecting animated figures on a screen so that a large number of people might simultaneously see them. The best known of these primitive plans is the *Zoetrope*, or "wheel of life," introduced by Desvignes in 1860, and still an amusing toy. A chain or series of slightly varying figures is observed through a number of slots in a vertical cylinder, so that when the figures and slots are in relative motion the figures look alive.

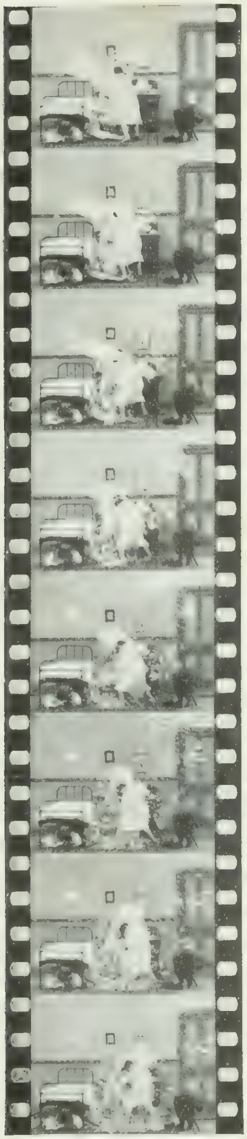


Photo supplied by R. W. Paul.

FIG. 2.—A ROLL OF FILMS: ACTUAL SIZE.

Compare with the enlargements on p. 245. Note also the perforations at the sides of the films.

In the *Praxinoscope*, by Reymand, which dates from 1877, the moving figures were seen reflected in a mirror, and also projected by a lantern on a screen.

Plateau had recognised the value of photography in getting models for his "phenakistoscope," and in 1861 Du Mont proposed to take photographs of living or moving objects at short intervals, and then combine them by passing them in quick succession before the eye so as to represent the movements of the object. It was not until 1870, however, that Marey in France, and Muybridge in America in 1872, successfully carried out this *chrono-photography*, as it is called, by photographing animals in motion, and reproducing their movements in "living photographs."

In 1874 Janssen, the astronomer, applied the method to obtaining views of the transit of the planet Venus across the disc of the sun, but it was only in 1891 that the celluloid film was substituted for the ordinary photographic plate, and chrono-photography came before the general public through Edison's *Kinetoscope*. In this well-known little apparatus very small photographs of a moving object are taken on a transparent film or moving band of celluloid at the rate of, say, forty-six a second, and these images are afterwards passed before the eye at the same speed. Since the images are small, they have to be enlarged by a lens, through which the observer peeps. Moreover, they are illuminated by means of an electric incandescent lamp behind the film, and a revolving shutter cuts off the light forty-six times a second. The film is in continuous movement, but the glimpses of the light permitted by the shutter are so brief that the picture seems to stand still.

The kinetoscope, however, merely showed the pictures on a small scale to one observer at a time, and many inventors now attacked the problem of making them visible to large audiences. In 1895 M. Lumiere, in France, introduced his *Cinematograph* for the purpose, and in the following year Mr. Robert W. Paul

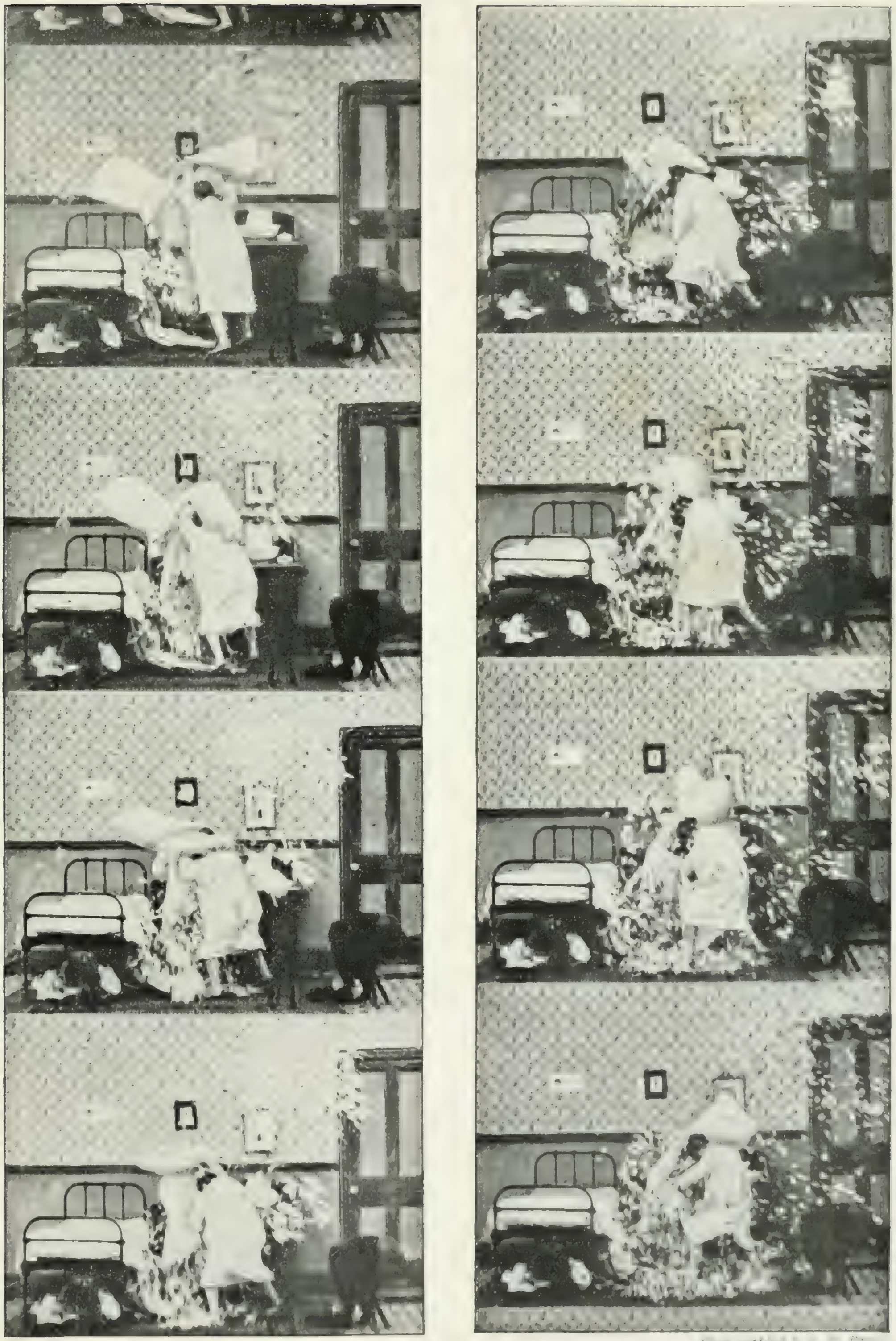


FIG. 3.—PROGRESS OF A PILLOW FIGHT AS SHOWN BY ANIMATOGRAPHY.

The films have been enlarged here and the perforations at the side removed. Compare with Fig. 2.

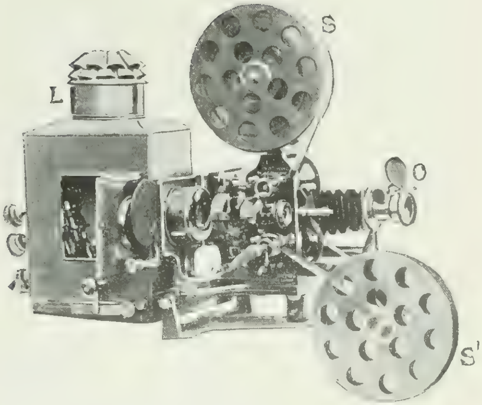


Photo supplied by R. W. Paul.

FIG. 4.—THE PROJECTOR.

L, *lantern;* O, *objective lens;* S, *upper spool;* S', *lower spool. The films are wound off the upper spool, pass before the condensing lens of the lantern, and are wound upon the lower spool.*

in England brought out his *Animatograph* which, as one of the first and most successful apparatus, has been chosen for special description.

As the pictures of the kinetoscope were only for individual inspection, the illumination was easily effected; but when it is remembered that in order to exhibit the photographs, which are only about the size of a postage stamp, to a large audience they have to be magnified by a lens 50,000 to 100,000 times, and projected by a powerful beam of light on a white sheet of canvas or screen, so as to blend them in one with sufficient accuracy to suppress any appearance of tremor, blurring, or contrast of light and darkness offensive to the sight, the mechanical difficulties of the problem will be apparent.

The successive photographs, as we know, are taken on a translucent strip of celluloid three-fourths of an inch apart (Fig. 2), to the number of twenty or thirty a second. The strip has to move so fast that from twenty to thirty photographs a second will pass before the eye, and to this end it is unwound from one spool or bobbin and wound upon another. The film must also be illumined from behind by a powerful beam of light, which has to be cut off by a shutter whilst the band moves the space of one photograph. Moreover, in order that enough light shall get through the picture to project it, the film, instead of moving continuously, has to stop for a little at each picture. In this way a photograph which has been projected on the screen is replaced by the next, and the shutter then allows a clear path for the rays to project it in turn. The strip has to stand still opposite the lens for as long a time as possible to give a bright illumination, and avoid the blurred effect on the screen which would arise if the picture were projected while the film was in motion. Fig. 3 shows the roll of films considerably enlarged. It will be observed that the difference in the position of the "moving" figures is comparatively slight as we pass from film to film.

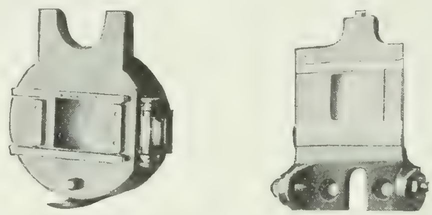


Photo supplied by R. W. Paul.

FIG. 5.—THE MECHANISM OF THE "GATE."

The "gate" serves to keep the film in "focus" and prevent strains and breakages.

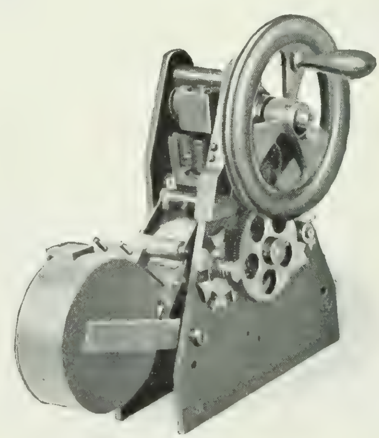


Photo supplied by R. W. Paul.

FIG. 6.—MACHINE WHICH MAKES THE PERFORATIONS ON THE FILMS.

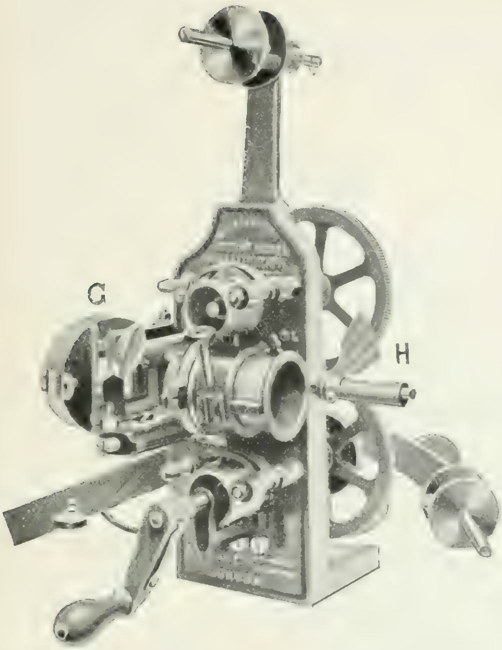


Photo supplied by R. W. Paul.

FIG. 7.—DETAILS OF PROJECTOR.
G, the gate; H, revolving shutter.

In the latest instruments, like that illustrated, the period of occultation or darkness has been greatly diminished, and the illumination of the picture on the screen much enhanced, whilst the flickering noticeable in the earlier stages of the invention, which was owing to the comparatively long time taken to move the film, has been rendered inappreciable.

Fig. 4 illustrates the new form of the animatograph projecting apparatus in combination with an ordinary optical lantern, so that one instrument serves the double purpose of projecting ordinary photographs, or lantern "slides," as well as animated photographs, on a screen. For this purpose the lantern *L*, which contains an electric lamp, shifts in its seat so as to throw its beam of light through the optical lantern *O*, seen behind, or else through the condensing lens, film, and objective lens of the animatograph in front. The film, in the meanwhile, is unwound automatically from the upper spool *S*, and, after passing before the condensing lens, is wound on the lower spool *S′*. The film, of course, must be intermittently moved past the lens without jerking, over-straining, or breaking it, and this is accomplished by a very ingenious mechanism, shown in Fig. 5. The film or band of transparent celluloid, bearing a series of pictures each 1 inch wide and $\frac{3}{4}$ inch high, is perforated on both edges with a row of holes, four to every picture. As it is unwound from the upper spool these holes engage in the teeth of a sprocket wheel or drum, *S*, over which the film travels continuously at one speed. The film then passes downwards through a device called a "gate," (*G*, Fig. 7), intended to keep it in the focus of the condensing lens, and after being stopped for a moment here in order that the image of a picture may be projected on the screen, it is pulled over a second sprocket wheel *S′* and wound on the lower spool. The machine which is employed to make the holes in the films will be noticed at Fig. 6.

The varying diameter of the coil of celluloid on the lower spool is compensated by a spring friction clutch, which allows

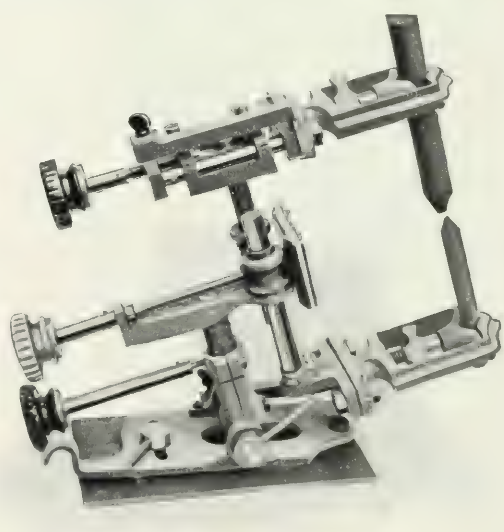


Photo supplied by R. W. Paul.

FIG. 8.—ARC LAMP WHICH FURNISHES THE LIGHT FOR THE "PICTURES."

Note the two large carbons in the front of the mechanism.

the driving power to slip as the spool fills, and therefore tends to wind up faster.

The intermittent movement, or stopping and starting of the film opposite the "gate" *G* (Fig. 7), or opening for the light to pass through the pictures, is effected gradually without shock or strain to the film by an admirable device in which a continuously moving driving roller engages tangentially with slots in another wheel, so as to turn it through one-third of a circle in one-sixteenth of its revolution. This produces a gradual increase and decrease of the speed of the driving roller, or what may be described as a "wave" of motion. At the same time, as a picture is being drawn away from the "gate" and another is taking its place, the shutter *H* (Fig. 7), which revolves just outside the objective lens where the beam is narrowest, cuts off the light. All this is done with extreme rapidity, and the period of occultation or eclipse in this apparatus is exceedingly small.

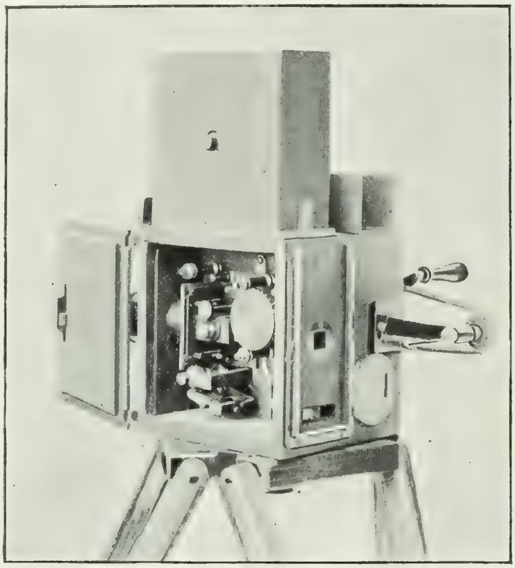


Photo supplied by R. W. Paul.

FIG. 9.—CAMERA USED FOR TAKING PHOTOGRAPHS FOR "LIVING PICTURES."

See also Fig. 1.

This much resembles an ordinary camera, save that the shutter is behind the objective lens, not in front of it. About thirty views a second can be taken with this camera.

The camera (Figs. 1 and 9) for taking the series of photographs on the film for reproduction as a "living picture" is very similar to the projector just described, except that the shutter in this case is behind, and not in front of, the lens. The latter, moreover, is designed for photography, not for projections; and the machine is operated by hand with a gearing that permits from twenty to thirty views a second being taken. The mechanism moves the film the space of one picture whilst the shutter screens it from the action of the light; then stops the film, and exposes it to the light by removing the shutter. The camera is, however, arranged so as to rewind the negative film inside a dark box, which is afterwards taken into a dark room and wound upon a wooden frame or drum, fitted with pegs. A number of "drums" is shown at Fig. 12. The frame is plunged into a tank of developer, and the film subsequently goes through the ordinary operations of fixing, washing, and drying (Fig. 10) for use.

In order to make a positive or "transparency" from this negative, a second perforated strip or blank film is required. The negative film, with the blank film below it, is then passed (*see* Fig. 11) through a "printing machine" consisting of a sprocket or toothed roller, which keeps them in "register," and in contact while being exposed to the rays of an electric incandescent lamp. The positive print thus obtained is developed, fixed, washed, and dried before it is ready for running through the projector.

The speeds of taking and projecting the photographs should, of course, be alike. Certain subjects are not reproduced as well as others. A breaking wave makes

a good subject, but a revolving wheel may not. Suppose, for example, that a cart-wheel has twenty spokes and turns

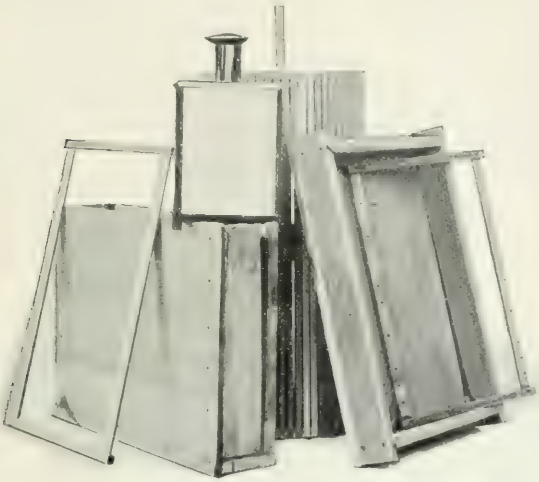


Photo supplied by R. W. Paul.

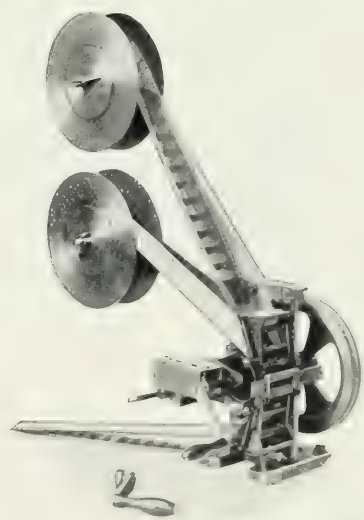
FIG. 10.—DRYING AND DEVELOPING FRAMES.

twice a second. If an operator takes twenty photographs of it a second, a spoke will occur in the same position in every picture, and the wheel will appear to stand still.

Animated photography is proving more and more useful in science and art. Pictures of animals in motion are, of course, a help to painters of the "life." Astronomers have employed it in registering the aspects of a solar eclipse, and botanists for illustrating the growth and development of plants. Such natural effects as breakers, tidal waves, or "bores" in rivers, geysers, and explosions can be studied at leisure by its means. Professor S. P. Thompson, F.R.S., by means of the animatograph, has presented to his audiences vivid illustrations of the changes in the invisible "lines of force" in electro-magnets and dynamos. An interesting fact not generally known is that the sound wave from an explosion casts a shadow, and though "snapshot" cameras fail to detect it, the animatograph succeeds in doing so.

Field sports, gymnastics, the operations of war, seafaring, ballooning, the launch of ships, the rush of express trains, and divers or fire brigades at work are nightly shown to large audiences. We can see Mr. Pickwick spending an old-fashioned Christmas at Mr. Wardle's, and share in the merriment when he kisses his hostess under the mistletoe or renews his youth in "hunt the slipper." We can follow 'Arry and 'Arriet on Bank Holiday down the river.

The pictures in some extravaganzas are coloured by tinting the film, but, in default of a direct process of colour photography, experiments are being made in the well-known direction of taking three separate photographs of the object through red, green, and blue screens, then projecting them through similar screens so as to combine them with their colours on the screen. If this three-



[illegible] plied by R. W. Pa[illegible]

FIG. 11.—MAKING "POSITIVE" FILMS UNDER THE ELECTRIC LIGHT.

N[illegible] the [illegible] roller which keeps the films in "[illegible]" and [illegible]

colour process can be applied on a large scale, it will certainly add a new charm to the world-wide interest in living photographs.

In the meantime, it may be safely claimed for the maker of "living pictures" that he has done much to show the public how modern science can lend itself to the amusement of the people, and we shall not be any the less interested at our next visit to a "living picture" gallery because we understand the way in which these pictures have been made.

Seeing how useful these photographs can be made as pictorial records of notable events, it seems a pity that there is no public repository or museum for their storage. Something of the kind has been suggested for phonographic records, and a museum of the latter kind has been established in Vienna, so that a museum of animatography may be amongst the possibilities of the future.

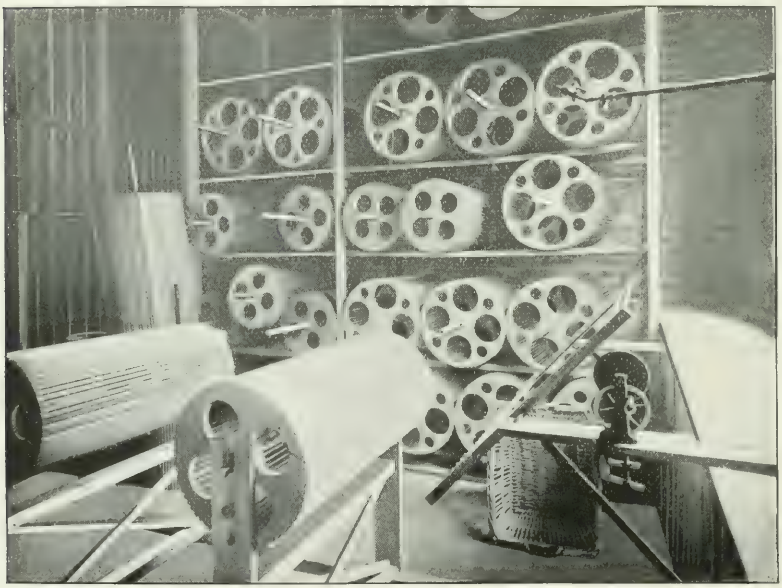


Photo supplied by R. W. Paul.

FIG. 12.—"DRUMS" UPON WHICH THE NEGATIVES ARE WOUND.

FIRE AND WATER STRUGGLING FOR MASTERY.

A LAVA STREAM FLOWING INTO A LAKE IN HAWAII.

6

THE STORY OF A VOLCANO AS TOLD IN HISTORY.

BY PROFESSOR T. G. BONNEY, D.Sc., LL.D., F.R.S., F.G.S.

As the train, bound from Rome to Naples, quits at Caserta the glens of the Apennines, a lofty mass rises prominently in front of the blue line of hills stretching away to the south-east, and by its apparent isolation at once attracts the eye. Its summit is formed by a long serrate ridge, behind or on which a cumulus cloud seems to rest even on the clearest day. This is usually the traveller's first view of Vesuvius—an important one, since it presents the mountain in what we may call a historic aspect. It was this form which it bore when Horace was a saunterer in "easy-going Naples," and when Virgil sang the praises of "charming Parthenope."

Photo: T. C. Hepworth.

FIG. 1.—VESUVIUS, WITH LAVA STREAM IN FOREGROUND.

The modern cone (for, compared with the old crater-ring of Somma, it is a thing of yesterday) is concealed from this point of view; and it is not till after some little time that a tooth on the right seems to detach itself from the rest of the ridge. This, as we proceed, gradually rises into greater prominence, and the mountain assumes the form rendered familiar to us by pictures exhibited everywhere—from the tops of work-boxes to the walls of academies—of a rather truncate cone, rising from a gently sloping base, and half inclosed on the left or northern side by a ring of broken crags.

Fig. 1 shows the mountain and part of the range, the rugged broken surface in the foreground being due to the torrents of lava which have from time to time been poured forth. A curious comparison is offered by this view and the one in Fig. 2, where appears the railway which

nowadays takes tourists nearly to the mouth of the crater.

For miles the shore at the foot of Vesuvius is fringed with houses, whose white walls glitter in the Italian sun, village linking on to village, to form a gigantic arm to Naples (*see* Fig. 3). The lower slopes of the mountain are densely clad with the vine and the olive, the citron and the orange, yet this vesture of verdure is stained by sombre blots, which once were molten rock; the cone itself is a vast pile of dark ashes; and on these sunny villages the fire from heaven has more than once fallen hardly less fiercely than on the cities of another plain.

Photo: T. C. Hepworth.

FIG. 2.—THE TAMING OF VESUVIUS: A RAILWAY RUNS NEARLY TO THE SUMMIT.

Note the "dip" of the roof in the foreground on the left. This gives some idea of the steepness of the ascent.

This, then, is the story of the volcano, as it has been gathered from the records of the past by more than one author. Till full three-quarters of the first century of the present era had elapsed, we read only of dim traditions of volcanic action. To picture the mountain as it appeared in the days of Virgil, we must efface the present cone; we must restore the cliffs of Somma to an unbroken ring, and imagine, within their inclosure, a wide amphitheatre, overgrown with trees and brushwood and wild vine. Once, indeed (73 B.C.), it served as a camp of refuge to a band of gladiators, who had escaped thither from the schools of Campania. Here they were for a time blockaded by Roman troops, but they scaled the cliffs by making ladders from the wild vines, defeated their foes by an attack in the rear, and began the Servile War.

So Vesuvius remained, through all the days of which history has preserved a record, till A.D. 79, a wide, circular, and perhaps rather shallow crater, overgrown with verdure, not unlike to, though loftier far than, Astroni, in the neighbouring Phlegræan fields, which is now used as a royal game preserve. The shores of the bay were studded with villages (as now) from Parthenope to Stabiæ,* probably not less numerous, certainly more opulent. We know Campania as it is, after centuries of misgovernment; then it was the "South Coast" in the palmiest days of Rome, and men took their pleasure with little stint on the slopes beloved, as the poets say, by the god of wine and the goddess of love.

The first interruption to the serenity of their life—to which a parallel may be found in the delightful story of the "Water Babies"—was a violent earthquake

* Modern: Naples to Castellamare.

FIG. 3.—NAPLES FROM THE MERGELLINA: VESUVIUS IN THE BACKGROUND.

After a Drawing by Birket Foster.

in the year 63 A.D. For sixteen years these subterranean warnings were continued at intervals. Then came the catastrophe, many details of which are preserved for us in a letter from the younger Pliny, who at the time was residing with his uncle, the commander of the Roman fleet at Misenum, on the western shore of the Bay of Naples. Thus he tells the story* :—" On the 24th of August, about one in the afternoon, my mother desired him to observe a cloud which appeared of a very unusual size and shape. . . . It was not at that distance discernible from what mountain this cloud issued, but it was found afterwards to ascend from Mount Vesuvius. I cannot give a more exact description of its figure than by resembling it to that of a pine tree,† for it shot up to a great height in the form of a trunk, which extended itself at the top into a sort of branches. It appeared sometimes bright and sometimes dark and spotted, as it was more or less impregnated with cinders." The old man, as he goes on to narrate, shortly after embarked for Resina, to render what help he could to the inhabitants of the towns along the coast. On approaching this place, " the cinders, which grew thicker and hotter the nearer he approached, fell into the ship, together with pumice-stone and black pieces of burning rock. They were likewise in danger not only of being aground by the sudden retreat of the sea, but also from the vast fragments which rolled down from the mountain." Accordingly, he changed his course a little, and landed at Stabiæ (now Castellamare), at a rather greater distance from the mountain. Though his friends were there in the utmost alarm, he took a bath and supped with calmness, and afterwards slept, until he was awakened because of the " court of his apartment being almost now filled with stones and ashes ; if he had continued there any time longer it would have been impossible for him to have made his way out." After consultation, it was decided to abandon the house and make for the shore. They set forth, having tied pillows upon their heads with napkins, to protect them from the storm of falling stones. " It was now day everywhere else, but there a greater darkness prevailed than in the most obscure night." The sea ran so high that it was unsafe to embark, and shortly after the old man fell down dead, apparently suffocated by some noxious vapour, which proved fatal to him, as he had long suffered from a difficulty of breathing. During this night earthquake shocks had been almost incessant at Misenum, and at last the relations whom he had left there quitted the house for the open country. On arriving in this, the chariots in which they rode " were agitated back and forward, so that we could not keep them steady. The sea seemed to roll back upon itself. On the other side, a black and dreadful cloud, bursting with an igneous serpentine vapour, darted out a long train of fire, resembling flashes of lightning, but much larger. . . . Soon afterwards, the cloud seemed to descend and cover the whole ocean, and the promontory of Misenum. . . . The ashes now began to fall upon us, though in no great quantity. I turned my head, and observed behind us a thick smoke, which came rolling after us like a torrent ; darkness overspread us like that of a room when it is shut up and all the lights extinct." Over all the land, from Sorrento to Capo di Miseno, the two horns of the Bay of Naples, this terrible " hailstorm " fell, till at last, when the sun shone dimly out, the ground was white with ashes as with fresh snow, and in the place of Herculaneum, Pompeii, and Stabiæ were wastes of volcanic scoria.

* Melmoth's Pliny, quoted by Phillips, " Vesuvius," p. 13.

† Pliny refers to the Stone Pine (*Pinus Pinea*) which has a general resemblance to our Scotch Fir.

Glimpses of portions of these buried cities will be found in Figs. 4, 5, and 6.

No lava appears to have been discharged during this eruption, or, at any rate, to have aided in destroying the towns. Herculaneum is chiefly overwhelmed with a volcanic mud, formed of the finer ashes mingled with water—a material not infrequently ejected from volcanic craters during eruption—which has now become hard and stony. Pompeii is buried beneath light, loose ashes. Subsequent eruptions may possibly have somewhat augmented these coverings ; but at the present time they are in places full eighty feet deep over the former, and twenty feet over the latter.

At the close of this eruption, the aspect of Vesuvius must have been completely changed. About one half the wall of the crater was probably blown completely away, leaving only the northern part—that now called Monte Somma—still standing. A new crater was doubtless formed within the old boundary, but its cone, so far as we know, was of no great height. Eruptions occurred after this, at intervals, for some thousand years ; but about the middle of the twelfth century a period of almost unbroken repose commenced, which lasted for five centuries. It is not easy to form an accurate idea of the appearance of the mountain during this period ; but probably a large, though not lofty, cone existed just within the imperfect ring of Somma, the interior of the latter being deep and level, while in one part were three pools, fed by hot mineral springs. Vegetation had again overspread the bare rocks, as it had done previous to the outbreak of 79.

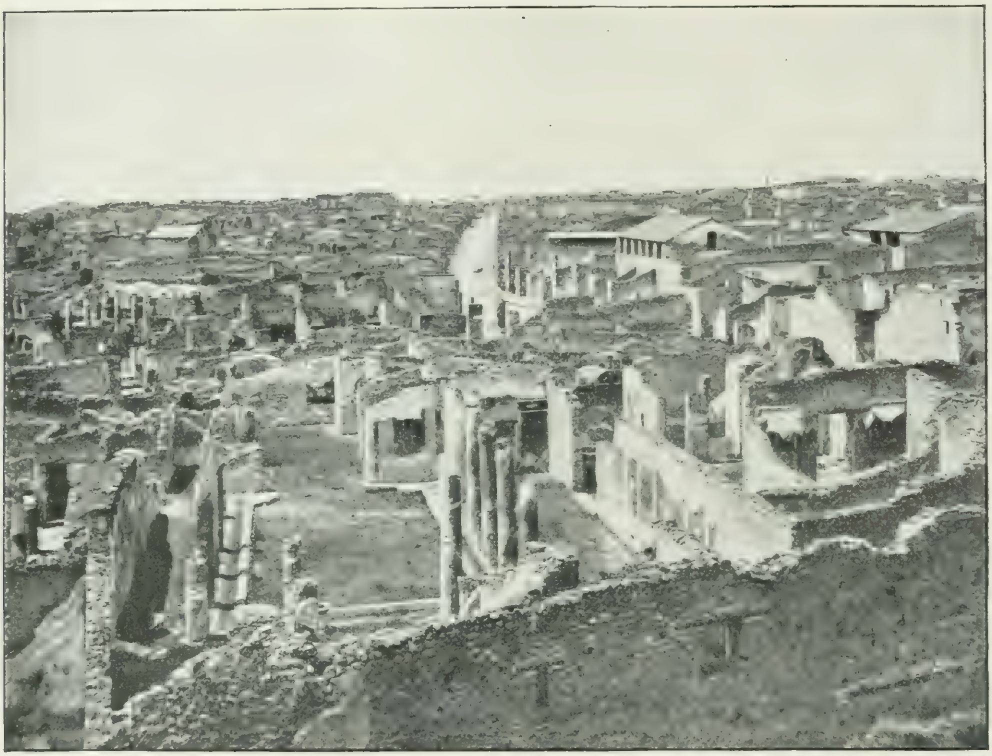


Photo : Alinari, Florence.

FIG. 4.—THE RUINS OF POMPEII : A GENERAL VIEW.

But in the year 1631 there was another awakening, hardly less terrible than the former. Again the surrounding region was shaken by earthquakes. A deep, continuous subterranean rumbling—a common phenomenon in volcanic eruptions—was heard, till at last the fatal morning of Tuesday, December 16th, dawned. Then the great pine-tree of dust and vapour—the volcano's black flag—once more rose up into the sky. Again the vapour spread, the lightning flashed, and the hail of scoria began. Great splashes of molten lava were launched into the air, and red-hot blocks fell thick about the mountain. About eleven o'clock a fissure opened out at the base of the cone, from which fresh showers of missiles were discharged, and a stream of lava began to flow. The people of Resina fled; but those of Torre del Greco lingered till the next day, when the lava burst forth with renewed violence, "so that the whole mountain seemed to be melting." They were quitting the town in a kind of procession, when suddenly a strange noise was heard, a torrent of molten lava debouched from a side street, and poured down upon the crowd. It parted; those in front escaped with difficulty; the rest found at once death and cremation beneath the fiery stream.

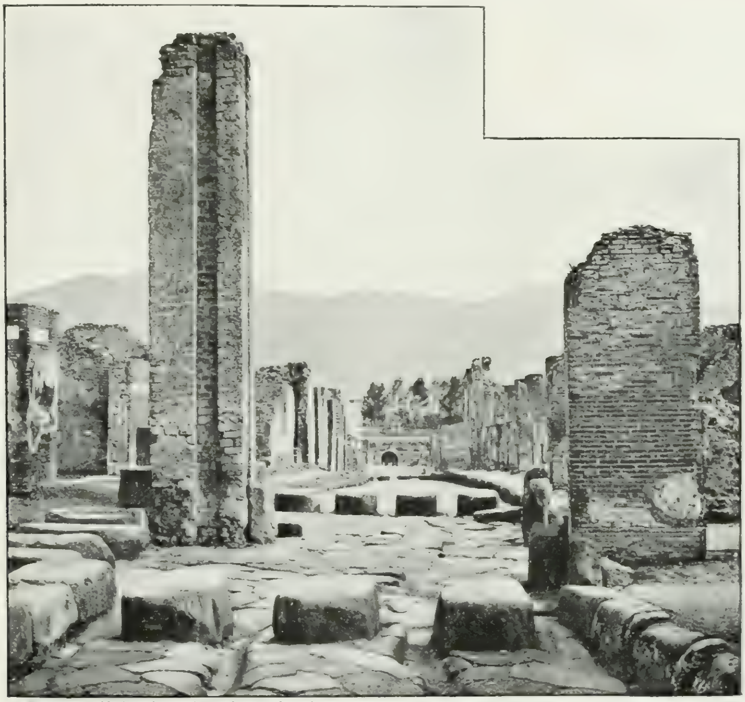


Photo: F. H. Worsham, West Dulwich, S.E.

FIG. 5.—A STREET IN POMPEII, SHOWING STEPPING STONES AND THE RUTS CAUSED BY THE CHARIOT WHEELS.

The broad streets are 24 feet, the narrow ones only 14 feet, wide. The sidewalks (trottoirs) are connected by means of the stepping stones.

When at last the eruption ceased, the cone had lost about a hundred and eighty yards in height, and had increased from two thousand to more than five thousand in circumference. The fertile plain of Campania was a desolate waste covered with acrid ashes. Such had been the violence of the explosion that these lay twelve palms deep at Ariano, six-and-thirty miles away; and stones

Photo: E. Brogi, Florence.

FIG. 6.—A VIEW OF POMPEII, SHOWING THE FORUM (ON THE RIGHT).

Pompeii was a seaport situated close to the mouth of the Sarnus, built about the year 600 B.C., and occupied successively by the Oscans, the Tyrrheno-Pelasgians, the Samnites, and the Romans. It was destroyed by an eruption of Vesuvius in A.D. 79, rediscovered by Fontana in 1592, and excavated at various times since that date. The uncovered ruins are elliptic in shape, and are nearly 3,000 yards in circumference.

of considerable size had been projected, it is said, to distances of more than sixteen leagues. Torrents of mud had injured the lands on the northern slopes of Somma, not much less than those of lava had devastated the southern slopes of Vesuvius. There, two great lava streams had been emitted—one, parting into several branches, had ravaged the country from Portici to Torre del Greco, the other the lands near Torre del Annunziata. Both had reached the sea in three or four places. Of the last town only about twenty houses remained. Parts of Resina and Torre del Greco were destroyed, and probably about two thousand persons perished.

From this time, Vesuvius has seldom been at rest for many years together. Violent eruptions have occurred, with the usual phenomena, and the form of the central cone has been frequently changed. In the early part of 1751, the mountain was capped by an inner cone and crater, built up in and overtopping the rim of a lower crater. This was utterly destroyed in the eruption which took place in the month of October; afterwards, there remained a crater rather more than a mile in circumference, and only 120 feet deep. Successive eruptions seem to have again built up the cone, and in 1779 there was an eruption hardly less violent than that which had occurred just seventeen centuries before. Sir W. Hamilton, who has left a most minute description of this eruption, tells us that the volcano shot up a column of molten matter, like "a fountain of liquid transparent fire," to a height of full ten thousand feet. This was swayed by the wind towards Ottajano, and covered in its fall the whole cone with a body of fire two miles broad. This town, on the northern slope of Somma, and three miles away from the crater, well-nigh met with the fate of Pompeii; the ashes lying in the streets as much as four feet deep. In 1794 there was an eruption hardly less violent, as the lava flowed through Torre

FIG. 7.—A RELIC OF THE GREAT DISASTER TO POMPEII.

del Greco to the sea. In 1822 the greater part of the central cone was engulfed, and its rim, instead of rising above the edge of Monte Somma, stood from three to four hundred feet below it. Since that time it has again been built up, and at present is about 4,250 feet above the sea, and nearly 500 above the highest part of Somma, and about 1,700 above the Atrio del Cavallo.

Such is the story of Vesuvius, one which may stand as a type for that of many volcanoes, illustrating the mode in which they are formed. Once it was thought that comparatively little of a crater was constructed of the piled-up scoria and lava driblets ejected from its orifice, but that when this opened strata previously horizontal were elevated in a conical form around it, by the upward pressure of gases and lava struggling to escape. Now it is held that such elevation takes place only to a slight degree, if at all, and that the greater part of a volcano is composed of the materials which it has vomited forth. In the story of the cone of Vesuvius—built up from the floor of Somma to a height of full 500 yards, and more than once almost totally destroyed and reconstructed—we see what the volcanic forces are competent to perform; and when, after examining the structure of the cone, with its driblets and dykes of lava and its irregular layers of scoria, we wander below the crags of Somma in the Atrio del Cavallo, or seek the ravines which the rills of rain-water have worn in its flanks, we notice that neither the lava-beds nor banks of ashes are regularly arranged or have a uniform slope, but present the same characteristics as those in the modern cone. We see that the floods of lava have not spread themselves out on level ground and then been tilted up, but have run irregularly, in driblets and clinkery streams, as if they had solidified on a slope, and that both they and the beds of scoria quickly change their character when traced horizontally.

Thus, in the history of Vesuvius—which is confirmed by that of every other volcanic mountain which has been carefully studied—we find evidence to show, beyond reasonable doubt, that a volcanic mountain is its own architect.

Photo: J. C. Hepworth.

FIG. 8.—STROMBOLI: THE LIGHTHOUSE OF THE MEDITERRANEAN.

This volcano, which has a height of 3,022 feet above sea level, is one of a group of volcanic islands, the Lipari Isles, off the northern coast of Sicily, and north-west of Messina. It is in this group that classical poets located the home of Vulcan.

TIME TOLD BY THE SUN.

SUN-DIALS are now seldom met with, though we may still occasionally see one fixed to the south side of an old church, or standing as an ornament in a garden. They are never regarded as serious tellers of the time, but half curio, half ornament, they speak to us of the days when they were much more common—when, before clocks and watches were invented, they were almost the only means of measuring time with any approach to accuracy. The sun-dial has been in use from the earliest times. The Hebrews were acquainted with it at least seven centuries before the Christian era. We all recollect the sign given by the prophet to King Hezekiah, that the shadow should go ten degrees backward on "the dial of Ahaz" (Isa. xxxviii. 8). The Greeks derived their knowledge of it from their Eastern neighbours, and by them it was introduced among the Romans. In our own country, down as late as the seventeenth century, no mathematical treatises were so common as those on dialling, and this branch of mathematical astronomy may still occasionally be met with in old text-books. The dial, of course, always laboured under the disadvantage of not being of any use in cloudy weather or after sunset; and hence, in very early times, it was customary to calculate the hours of night from the position of some prominent star. Arago tells us that the Abbot of Cluny consulted the stars when he wished to know the time for midnight prayers; at other times a monk remained awake, and in order to measure the lapse of time repeated certain Psalms, having learnt by experiment how many he could say in an hour.

The principle on which the sun-dial is constructed may be easily explained. Owing to the earth's rotation, the sun appears to move round our globe in twenty-four hours. The circumference of the earth is, of course, a circle, and every circle is divided into 360 degrees. Hence the sun appears to pass over 360 degrees in twenty-four hours, or fifteen degrees in one hour. When, at any place, the sun reaches the meridian—that is, its greatest altitude on any given day—it is said to be noon, and we call the hour twelve. Suppose, then, that it is twelve o'clock at Greenwich, it will be evident, from what has been said, that at a place fifteen degrees to the west of Greenwich it will be eleven, while at a place fifteen degrees east it will be one o'clock. Let P, B, P′, D (Fig. 1), represent the earth as a hollow, transparent sphere, having an axis P, E, P′, on which it turns. P, P′, will be the poles of the axis, and the dotted line midway between them will represent the equator. Let the equator be divided into twenty-four equal parts, and through these divisions draw the meridians 1, 2, 3, etc. These meridians will, of course, be fifteen degrees apart. For the sake of clearness only twelve of these are shown in the diagram. Let B be a point about fifty degrees north of the equator—and therefore somewhere in the neighbourhood of London—and let us suppose the sphere cut through by the horizontal plane A, B, C, D. Now if the axis P, E, P′ be opaque, the sun in its apparent motion round the earth—caused, as we know, by the earth's rotation on its axis—will pass from one meridian to another at regular intervals of one hour, and cause the shadow of the axis to fall upon the horizontal plane. Thus, if at one o'clock it falls upon the point B, an hour later the shadow will be on II.; two hours later, at III.; and so on. An hour before one, the shadow will be at XII.

Now in a sun-dial the plane A, B, C, D may be represented by a horizontal slab of slate, marble, or brass. A triangular piece of metal, similar to *a*, *c*, *b* (Fig. 2),

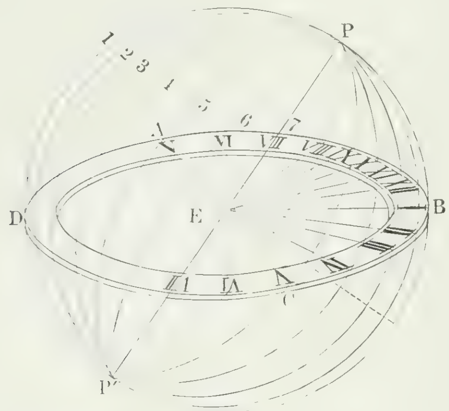


FIG. I.—SHOWING THE PRINCIPLE UPON WHICH A SUN-DIAL IS CONSTRUCTED.

called a gnomon, stands perpendicularly on the slab, the line *a*, *b* being due north and south. The line *a*, *c*, called the style, points to the Pole star, and is therefore parallel with the earth's axis, and thus corresponds with P, E, P′. When the sun is on the meridian, the point where the shadow of the gnomon falls is marked XII. Earlier in the day the shadow falls to the west of this point; later, it falls on the eastern side. The dial-plate is carefully graduated according to well-known rules, which we need not stop to consider, and thus, if the dial has been correctly made, any hour between sunrise and sunset may be ascertained by consulting it on a bright day. "*Horas non numero nisi serenas*" ("I only count the hours of sunshine") was an ancient dial motto. We have spoken only of the horizontal sun-dial, but in the vertical dial the principle is precisely the same—the style must in all cases point to the Pole star.

It will be obvious from what has been stated that a sun-dial made for London would be useless for either Paris or Edinburgh. The altitude of the Pole star varies with the latitude, and hence is greater at Edinburgh, and less at Paris, than at London; and as the style must always point to the Pole star, the angle which the line *a c* makes with the dial plate must vary with the latitude.

Suppose some bright day, about noon, we come across a sun-dial, and have the curiosity to examine it, and to compare it with our watch or the neighbouring church clock. The chances are that we shall find that the dial will differ a few minutes—perhaps as much as a quarter of an hour—from our watch or the clock. If we compare the dial with the clock, at intervals for a week or two, we shall find that the times which they indicate vary in a remarkable way. Thus, if we examine the sun-dial early in March, we shall find it about ten minutes slow when compared with a clock; a month later the difference will be only about one minute slow; in May we shall find it three or four minutes fast. The question naturally arises, Which is right—the sun or the clock? At first we incline in favour of the sun, for he is the recognised ruler of the day; and besides, he has no complicated system of wheels to get out of order. But let us not decide hastily.

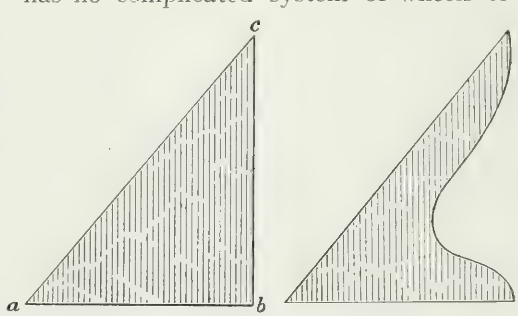


FIG. 2.—TWO FORMS OF "GNOMON."
The line a c points to the Pole star; a b lies north and south.

The relative daily motion of the sun we know is only apparent; it is caused by the daily rotation of the earth upon its axis. But this also causes an apparent movement among the stars. Is their

motion regular, or does it seem to vary like that of the sun? Suppose on some clear night we notice a bright star in a line with a church spire, the top of a tree, or some tall chimney, and carefully note the exact time as well as the exact position. If we look for that star the next evening we shall observe it in the same position, probably a little earlier than we expected. If it was ten o'clock the night before, it will want four minutes to ten now. And

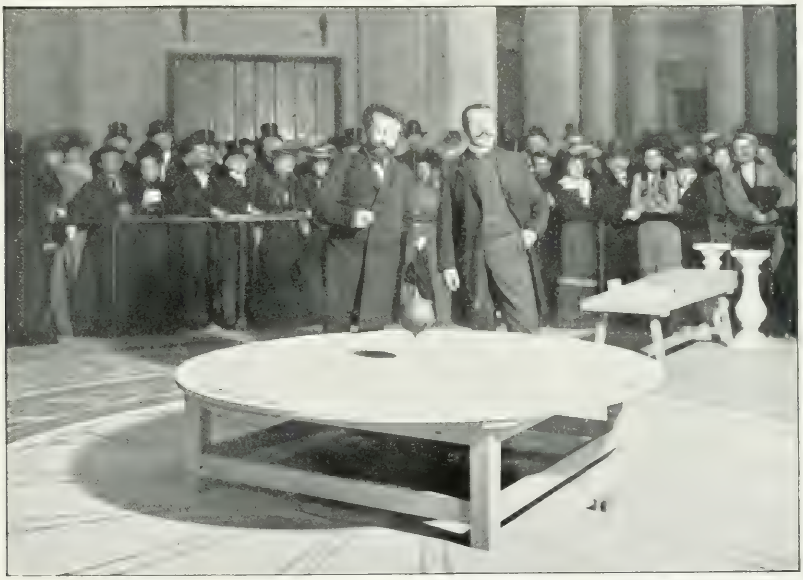


FIG. 3.—FOUCAULT'S PENDULUM AT THE PANTHÉON, PARIS.

The pendulum is made of a ball of lead weighing 28 kilos, suspended by a piano string 64 metres long. The knife fastened upon the under side of the leaden ball traces a fresh line in the sand upon the table at each swing of the gigantic pendulum, and the plane of its swing seems to make a complete revolution in 24 hours. Proof is thus obtained of the earth's rotation.

if we continue our observations night after night, we shall find that it always occupies exactly the same interval of time in returning to the place where we first observed it. This interval is 23 hours 56 minutes, or very nearly so. Thus, at the end of a fortnight we may look for the star at nine o'clock instead of ten; at the end of a month, about eight o'clock. Here, then, is another difficulty. The apparent motion of both the stars and the sun is caused by the earth's rotation; the stars complete a revolution in 23 hours 56 minutes; the sun requires 24 hours. How do we account for this difference of four minutes? And what is the exact time which the earth requires to make one revolution upon its axis? Now we must remember that the apparent motion of the stars never varies, while the apparent motion of the sun does vary, as the sun-dial proves. Both of them are caused by the earth's rotation, and this rotation, it is natural to suppose, is uniform. If we watch a top spinning we see that for a time its motion is perfectly uniform; there is no change from quick to slower and then again to quicker motion. The rotation is gradually overcome by friction. If it were not for this, once started it might spin for ever. The earth spins round just like a top, but there is no friction, and hence it goes on with a uniform motion from day to day, and from year to year. The exact time it takes to make one revolution is that indicated by the stars—23 hours 56 minutes. This is called a *sidereal* day.

But now two other questions arise.

Why is a solar day about four minutes longer than a sidereal day? And why do solar days vary in length?

We know that the earth has two motions. Besides the diurnal or daily motion on its own axis, there is an annual motion round the sun. It is this annual motion which causes the difference between solar and sidereal days. This may be explained by a diagram. Let A, B (Fig. 4) be a portion of the earth's orbit, and E, E′ the earth in two different positions. Suppose when the earth is at E that an observer at *a* sees the sun on the meridian; then it is evident that if the earth were stationary in its orbit the point *a* would, by the earth's rotation, be brought round to the same position again in 23 hours 56 minutes, and the solar days and the sidereal days would be of the same length. But while the earth is making one revolution upon its axis it is also moving forward in its orbit, and has reached E′. An observer at *a* will not now see the sun on the meridian, but a little to the east, and the earth must turn a little more to bring the sun on to the meridian, and it requires about four minutes to give this little extra turn. Hence it will be seen that in a solar day the earth makes rather more than one revolution upon its axis. It might be thought that the movement of the earth in its orbit would also affect the position of the stars in the same way. But these bodies are at such immense distances from us that the movement of the earth from one side of its orbit to the other causes only the very slightest change in the apparent position of even the stars nearest to us.

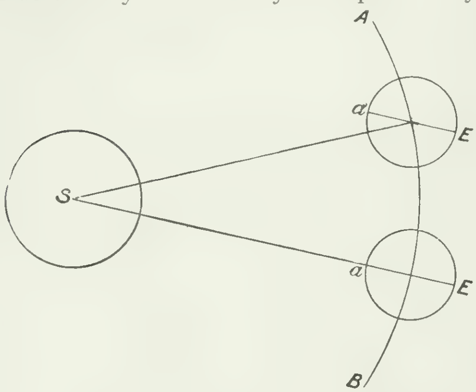


FIG. 4.—ILLUSTRATING THE DIFFERENCE BETWEEN SOLAR AND SIDEREAL DAYS.

We have now to consider the second question—Why are not the solar days all of the same length? There are two reasons for this. First, because the motion of the earth in its orbit is not uniform. Secondly, because the ecliptic does not coincide with the celestial equator.

Fig. 5 shows the earth in different parts of its orbit. The positions A and C are called respectively the summer and winter solstices; B and D, the equinoxes. The earth's orbit is not a

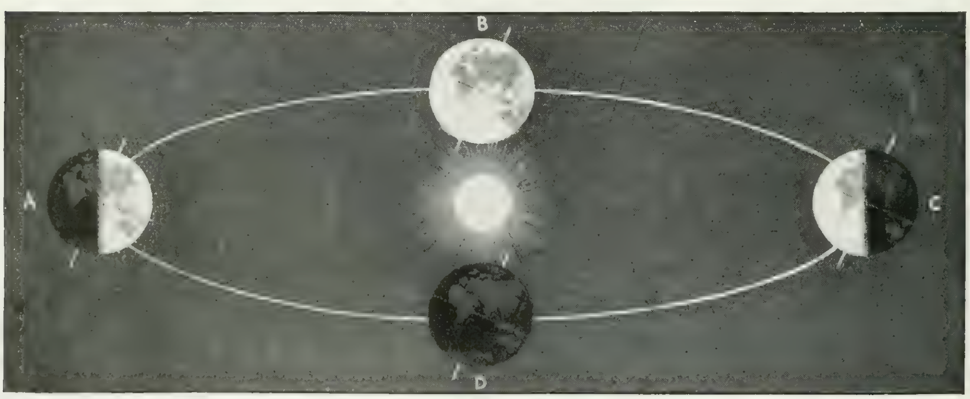


FIG. 5.—SHOWING THE EARTH AT VARIOUS POINTS IN ITS ORBIT.
A. Summer, C. Winter solstice. B. and D. The equinoxes.

perfect circle, but an ellipse. In winter we are three million miles nearer the sun than in summer. Some may think that if this statement be correct we ought to have warmer days in winter. But the heat which we receive from the sun depends very much upon the direction of its rays. We all know that it is much hotter at noon than early in the morning. In summer the sun's rays are more vertical than in winter; hence the days are warmer. Now, just as a falling stone moves more quickly as it approaches the ground, so the earth moves more quickly in its orbit as it approaches the sun. In

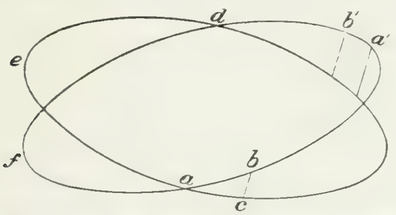


FIG. 6.—INCLINATION OF THE EARTH'S AXIS TO THE PLANE OF THE ECLIPTIC.

the winter months, therefore, the earth is moving more rapidly than at any other time; in the summer months more slowly. A glance at Fig. 4 will show that this must make a difference in the length of solar days. The difference in length between a solar and a sidereal day depends upon the distance from E to E′. If the earth's annual motion were uniform, this distance would always be the same; but since the earth's motion is not uniform, this distance varies, and consequently the length of the solar days must vary.

But even supposing the earth's motion in its orbit were perfectly uniform, there is another circumstance which would cause the solar days to vary in length. In Fig. 5 the straight lines drawn through the globes represent the inclination of the earth's axis to the plane of the ecliptic. By ecliptic we mean the apparent path of the sun among the stars caused by the earth's annual motion. The earth's orbit lies in the plane of the ecliptic—that is, on the same level—but a glance at the diagram will show that the equator does not lie in this plane, but is inclined to it at a considerable angle. At the summer solstice the sun is vertical at a point 23½° north of the equator; at the winter solstice, 23½° south; at the equinoxes it is vertical at the equator. In an artificial globe a circle is sometimes drawn to represent the sun's path. When this is the case, we see that it bisects the equator in two points, and recedes from it on either side to the tropics of Cancer and Capricorn, which are 23½° north and south of the equator respectively. The ecliptic, however, we must recollect, is not an imaginary circle upon the earth, but in the heavens; and there is also a circle corresponding to the equator called the celestial equator. These two celestial circles, however, have the same inclination to each other as the circles sometimes drawn upon the artificial globe. Let the circle *a c d e* (Fig. 6) represent the celestial equator, and *b a′ b′ f*, the ecliptic. Now, owing to the earth's annual motion, the sun appears to travel round the ecliptic in the course of a year. If the earth's motion were perfectly uniform the distance travelled by the sun along the ecliptic would be exactly the same every day, but its progress eastward would not always appear the same. All measurements to the east and west have reference to the equator, just as all measurements to the north and south have reference to the poles. A glance at the diagram will show that the distance *a b* is not the same as *a c*, so that near the equinoxes the sun's apparent daily motion to the eastward is less than the average. On the other hand, at the solstices, the distance travelled by the sun in one day—from *a′* to *b′*—is the same when measured on the celestial equator. As a matter of fact, solar days near the equinoxes are twenty seconds shorter, and at

the solstices twenty seconds longer than the average.

Thus we see that even if the motion of the earth in its orbit were uniform there would be a difference in the length of solar days; but the motion, as we have seen, is not uniform. The consequence of the two causes combined is that we never get two solar days together of exactly the same length. They do not vary from each other more than about fifty seconds, but this difference may go on accumulating for weeks together, so that sometimes there is as much as sixteen minutes' difference between *apparent* time—that is to say, time as shown by a sun-dial, as it appears to be directly indicated by the sun itself, and the time as shown by a clock. The time given by a clock is called *mean* time, for a clock or watch is necessarily constructed to go at a uniform rate throughout the year, and hence a day, according to the clock, must be of the *average length of the solar day*. This day is divided into exactly twenty-four hours. At certain periods of the year a number of short solar days may come together, and then the sun is behind the clock. At another period a number of long solar days come together, and then the sun is before the clock. There are only four days in the year when the clock and the sun-dial agree. These are April 15th, June 15th, August 31st, and December 24th. The difference between *apparent* time and *mean* time is called the *equation of time*. It can be calculated beforehand for every day in the year, and is sometimes printed in almanacs, and occasionally on the face of large dials. In order to make use of this table we should notice carefully the exact time indicated by the sun-dial; then, turning to the table, find out whether the sun is before the clock or behind, and how much. If, then, we make the necessary addition or subtraction, we get correct time, and can then test our watches or the neighbouring church clock.

The Sun-dial, Temple.
(FIG. 7.)

The introduction and spread of railways has occasioned a distinction between two other classes of time. As already noted, when it is noon at Greenwich it is eleven o'clock at a place fifteen degrees to the west of Greenwich, whilst at a place fifteen degrees east it will be one o'clock. Since fifteen degrees make an hour's difference, one degree will make a difference of four minutes. Thus it is noon at Greenwich eight minutes before it is noon at Liverpool and five-and-twenty minutes before it is noon at Dublin. This difference between the times at different places

was of no consequence when the rate of travelling was slow, but it was soon felt that it involved a real inconvenience when the introduction of railways made it possible to travel at sixty miles an hour. Thus the guard of a train leaving Paddington for Bristol would find his watch—which was correct by London time when he left Paddington—fast when he got to Reading, and faster still (eleven minutes fast, in fact) at Bristol. But returning, if he set his watch by Bristol time ere he started, he would find it slow at each station as the train went eastward; and the up-trains—the trains to London—would seem to take twenty-two minutes longer in their journeys than the down-trains, supposing that both went at precisely the same rate, and that the times of starting and arrival were taken from the places from which the trains started and at which they arrived. In order, therefore, that railway time-tables should not be needlessly complicated, London time—or, rather, Greenwich time, the time as determined at our great national observatory—was adopted for the running of trains all over the country. At first towns in the provinces kept not only *railway* time but their own *local* time; but it was soon felt that since the time of Land's End even differed only twenty-three minutes from that of Greenwich, there would be no great inconvenience in using Greenwich time all over the country, and it is, therefore, now employed practically everywhere, and local time has almost fallen out of use.

But when the American continent was crossed by railway lines, a very much more complicated difficulty had to be faced. In the United States, for instance, the difference in local times between the States of Maine and California amounted not to a few minutes, but to five hours, and it was felt that it was too much to ask the people to speak of seven o'clock in the morning, or five o'clock in the evening, as if it were noon. A compromise was therefore adopted, and the country was divided into four sections, each, roughly speaking, fifteen degrees broad, and each section keeping a local time of its own, which differed by an exact hour from that of the section on either side. The question then arose as to how these four

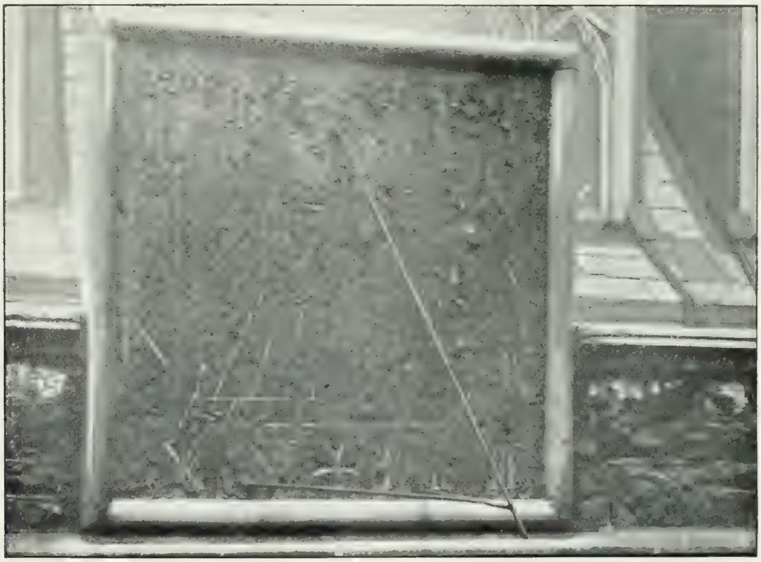


FIG. 8.—A VERY OLD SUN-DIAL AT THE DUTCH CHURCH, AUSTIN FRIARS, LONDON.

different *standard* times should be related to the standard times of England, and it was decided that they should differ from Greenwich time by exactly five, six, seven, and eight hours respectively. The example thus set by the United States and Canada has been followed by nearly all the other civilised nations of the world, and practically the standard time for every country is either Greenwich time, or differs from it by an exact number of hours or, in one or two cases where this arrangement would have been inconvenient, by an exact number of half-hours.

The earth completes a revolution round the sun in $365\frac{1}{4}$ days—or, more exactly, 365 days 5 hours 48 minutes 49 seconds. The year is divided into months, and these, as the name indicates (Saxon, *monath*, from *mona*, the moon), were originally —in this country, at any rate—regulated by changes in the moon. The average time, from new moon to new moon, is 29 days 12 hours 44 minutes and 2·87 seconds; so that, in round numbers, we may say thirty days. But twelve months of thirty days each would only give us 360 days. To certain months, therefore, we assign 31 days, to make up the complete year. We obtain the names of the months from the Romans, who originally only had ten months in the year. We can find a trace of this fact in the names September, October, November, December—which mean the seventh, eighth, ninth, and tenth months respectively. It was soon noticed however, that ten months were not sufficient, and two more—January and February—were added, which originally had 28 days each. The number of days in January was subsequently raised to 31, but February still retains its 28 days. In the time of Julius Cæsar the Roman calendar had got into great confusion. Among other irregularities, the vernal equinox (March 21st) was almost two months later than it ought to be. To remedy this, two months were inserted between November and December, so that that particular year (B.C. 46) had fourteen months. The number of days was correctly fixed at $365\frac{1}{4}$, and to get rid of the quarter it was decided to intercalate — that is, to interpose — a day between February 23rd and 24th. This was done by counting February 24th twice. February 24th was then called *sextilis*, or sixth—that is, the sixth day before March 1st; and when this day was reckoned twice the year was called *bissextile*, or double sixth. We add an extra day to the month instead, and call it *leap* year. The reason for this name seems to be that in ordinary years Christmas Day and other fixed festivals fall one day later in the week each succeeding year, but in leap year they are two days later; there is a leap over one day. Thus in 1902 Christmas Day fell on a Thursday; in 1903 it fell on a Friday; but in 1904, being a leap year, it was two

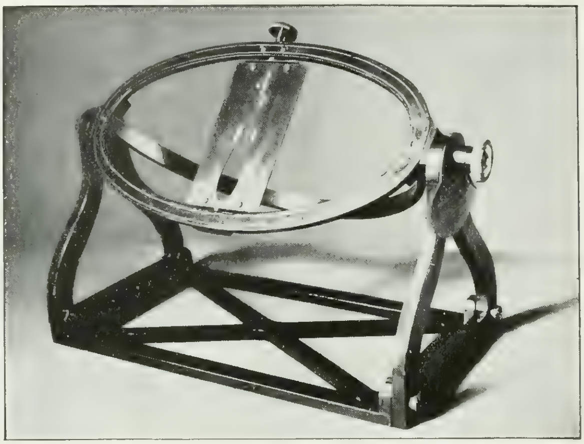


FIG. 9.—A MODERN SUN-DIAL SHOWING MEAN TIME.
The invention of Major-General Oliver.

days later, viz. on a Sunday. The efforts of Julius Cæsar to reform the calendar were commemorated by the name of one of the months, which was changed from Quintilis to July.

But we have seen that a year is not exactly 365¼ days, but about eleven minutes short of this; and though this does not seem much, yet it amounts to a whole day in 130 years. The consequence of this was that towards the close of the sixteenth century it was found that the calendar again stood in need of reform. An Italian physician projected a plan for its reformation. This, on being presented to Pope Gregory XIII., was submitted to a conference of prelates and learned men, and adopted, and in 1582 a papal brief was issued abolishing the Julian calendar in all Catholic countries, and introducing in its stead the one now in use under the name of the *Gregorian*, or reformed, calendar. It is also sometimes called the *new style*, to distinguish it from the Julian, or *old style*. The chief alterations were these: ten days were dropped after October 4th, 1582, and the 15th was reckoned in immediately after the 4th. To prevent any error in future, every one-hundredth year—which, by the old style, was to have been a leap year—was now to be a common year, the fourth excepted. Thus, 1600 was to remain a leap year, but 1700, 1800, and 1900 were to be of the ordinary length, and 2000 a leap year again.

For a long time, however, the Protestant countries of Europe would not adopt the new style, and it was not until 1751 that England did so. In that year the famous Lord Chesterfield introduced a bill into Parliament, and the measure received the royal assent. But it met with much opposition out of doors. The great body of the people regarded the measure as impious and popish, and as eleven days had to be omitted in the month of September so as to bring the calendar into unison with the equinoxes, people had an idea that they were being robbed of eleven days. By this bill, also, the year was made to commence with January 1st instead of March 25th, as it had done previously. Russia, and those countries which belong to the Greek Church, still follow the old style, and hence in Russia Christmas Day falls on what we call January 6th, for the discrepancy between the old style and the astronomical year now amounts to twelve days.

A curious attempt was made at the time of the French Revolution to introduce an entirely new calendar. The year was made to consist of twelve months of 30 days each, and to complete the full number five fête days (in leap years six) were added to the end of the year. Each month was divided into three parts, called *decades*, of ten days each. The time fixed for the new reckoning to commence was the autumnal equinox (September 22nd) of 1792. The old names of the months were dropped, and new ones, descriptive of the time of year, adopted—such as windy month, rainy month, foggy month, harvest month, and fruit month. An attempt was also made to carry the decimal mode of reckoning into the hours of the day; thus the day was divided into ten parts, and these subdivided into hundreds and thousands. This, of course, involved an entire change in the dial plates of clocks and watches, and a decree was issued to this effect. But the new mode of reckoning, as might be expected, perplexed and puzzled ordinary people, and the attempt had to be abandoned. In 1805, when Napoleon became emperor, the entire calendar was abolished, and the Gregorian calendar re-established.

COAL GAS.

IN the early part of the eighteenth century the then Dean of Kildare, the Rev. John Clayton, noticed a ditch about two miles from Wigan, in Lancashire, wherein the water, as he tells us, would seemingly burn like brandy, and the flame whereof was so fierce that several strangers succeeded in boiling eggs over it.

Desiring to ascertain the cause of this phenomenon, Mr. Clayton hired a person to make a dam in the ditch, remove the water, and then dig down into the earth. When the excavation had reached nearly half a yard in depth, a bed of coal was reached; a lighted candle was then put down into the hole, when the "air" caught fire and continued to burn. In order to prove the truth of his supposition that the inflammable air and the coal were somehow connected with each other, he procured a sample of the latter, and subjected it to distillation in a retort heated by means of an open fire. At first there was produced only a "phlegm," but afterwards there appeared a black oil, and finally a "spirit arose." This spirit he could "in no way condense," but he found that as it issued out in a stream it very readily caught fire when brought into contact with a lighted candle, and continued to burn with violence.

Having a mind, as he says, to try if he could save any of this *spirit*, Mr. Clayton adjusted a turbinated receiver to his apparatus, and to the exit-pipe of the receiver he attached an empty bladder, which as the *spirit* rose was blown up and filled. The *spirit*, as thus stored in the bladders, he again tried in various ways to condense, but all his efforts in this direction were in vain.

"Then," to use his own words, "having a mind to divert strangers or friends, I have frequently taken out one of these bladders and pricked a hole therein with a pin, and compressing gently the bladder near the flame of a candle till it once took fire, it would then continue flaming till all the spirit was compressed out of the bladder; which was the more surprising because no one could discover any difference between these bladders and those which were filled with common air."

Thus was coal gas discovered; and it is curious and interesting to note that the process which Mr. Clayton employed to manufacture one or two bladders full of the gas with which to amuse his friends is essentially the same as that which is employed in the present day for the production of the enormous quantities of this material, now used so extensively as a source of light and heat.

Upwards of a century and a half has passed away since the discovery of coal gas was made, and yet barely three-quarters of a century have elapsed since it came into general use as an illuminating agent. Various reasons have been assigned for this long delay in the useful application of this most important discovery. As was to be expected, such a notable discovery as that of Mr. Clayton led to many experiments being made, but these were mainly of a philosophical character. Not, however, till the year 1798 was gas used commercially as a substitute for the old-fashioned oil lamps and candles, and even then it was employed to a very limited extent only.

The discovery of the practical utility of coal gas for illuminating purposes has generally been credited to William Murdoch, then residing at Redruth, in Cornwall, and the year 1792 named as the date of the application of the dis-

covery. It appears, however, that Professor Minckelers, of Limburg, Holland, has a prior claim to the credit. It is said that as far back as 1783—nine years before Mr. Murdoch entered the field—Professor Minckelers hit upon the new illuminant whilst experimenting in search of a cheaper gas than hydrogen for inflating balloons. He first obtained the "new" gas by heating crushed coal in a gun barrel, thus recalling the experiment of the production of gas by means of a tobacco pipe, alluded to later. The professor's lecture room at Louvain is said to have been lit with coal gas soon after. Inflammable gas had been derived from coal even earlier than 1783—to wit, by Beche, in Germany, in 1680, and in Great Britain by Clayton in 1739.

In the year 1805 the cotton mills of Messrs. Phillips and Lee at Salford were lighted with gas; in 1809 an application was made to Parliament for an Act to incorporate a company, to be called "The London and Westminster Chartered Gas-light and Coke Company," and the following year the charter was granted. The newly formed company, though it had now obtained a charter from Parliament, met with much opposition from the general public. The idea of lighting a town with gas was looked upon as purely visionary; and as illustration of the opinions held by even some of the foremost men of the time it may be mentioned that Sir (at that time Mr.) Humphry Davy regarded the proposal as being so supremely ridiculous that he asked scornfully whether it was intended to take the dome of St. Paul's for a gas-holder.

FIG. I.—GASOMETER AT BATTERSEA PARK.

The engineer to whom the question was addressed had evidently formed a better opinion of the future in store for gas illumination than that possessed by the great chemist, for he answered by confidently expressing the hope that he might live to see the day when gas-holders would not be much smaller. This hope, the utterance of which was, no doubt, regarded as empty boasting, was realised far beyond what was ever evidently expected. The dome of St. Paul's is 145 feet in diameter, and there are gas-holders in existence to-day which exceed 200 feet in diameter.

The new gas company, meanwhile, struggled on against all opposition, going so far even as to supply many shops and houses with gas for nothing, in order, if at all possible, to entice the public to look with favour on the new light. This state of matters continued for nearly two years, and then slowly, one by one, the many obstacles in the way were surmounted. These obstacles, however, were neither few nor trivial. In the first place there was the unaccountably great and apparently perfectly unfounded prejudice entertained against gas, not only by the general public, but also by many eminent scientific men. Then the insurance companies raised many objections, one at least of which was extremely frivolous. If a gas-burner was left open accidentally, they asked in horror, what would be the consequence? To meet this a special burner was invented, which, however, was never afterwards used.

Following the lead of the insurance companies, the Government next interfered. They were not sure but that some demon of destruction might be lurking undetected in the apparatus in connection with the much-suspected gas-flame. They accordingly deputed a number of gentlemen to proceed to the works of the unfortunate gas company, and make a careful inspection of their premises, the result of which inspection was that the deputation strongly advised the Government to insist that the company should only erect small gas-holders, and that these, when erected, should be enclosed in strong buildings.

The first part of this recommendation was made apparently in the belief that gas-holders are liable to explode, many people then, as now, believing that if a light were introduced into one of these large vessels a most disastrous explosion would immediately result. The fact of the matter is, that if a light were put inside one of these gas-holders it would simply be quietly extinguished without even igniting the gas. Gas will not burn, much less explode, until it comes into contact with the air; and these gas-holders contain not an explosive mixture of gas and air, but merely gas, pure and unmixed, and therefore perfectly incapable of exploding. In these early days, however, the properties of gas were not so well understood as they are now, and therefore we can excuse the first part of the recommendation made by the deputation. The second part, however, in which they advised that the gas-holders should be surrounded with substantial buildings, is totally inexcusable. If the gas-holders were not liable to explosion, these buildings were not required; and if there was any likelihood of their exploding, the presence of the buildings, far from doing any good, would, in the event of an explosion, increase the disastrous effects tenfold. The company protested and explained, but all in vain; they were compelled to erect the expensive and useless buildings.

Nor were their troubles yet at an end. On the occasion of the rejoicings for the Peace in June, 1814, it was proposed to have a grand public illumination by means of the new light. For this purpose a large wooden structure was, by order of the Government, erected in St. James's Park. This was provided with more than ten thousand gas-burners, which, by an ingenious arrangement, were made to catch fire one from the other, so that by simply applying a light to one of the burners the whole ten thousand were ignited with great rapidity, and the entire structure, some eighty feet in height, appeared in a few seconds as if it were a solid mass of flame, thus presenting an exceedingly grand appearance. The illumination was very successful when tried on the previous night; the next night, however, one of the officials in command insisted, contrary to the advice

of the gas engineer, upon letting off some fireworks from the wooden stage before the illumination took place, the result of which was that the vast structure was burned to the ground before the gas was turned on. A report was circulated that the fire was caused by the gas, and this unfortunately being generally believed, the progress of gas illumination received another serious check. Next year, however, the Guildhall was lighted with gas, November 9th being the day fixed for the first trial. Here, happily, everything was successful, and the new light on this occasion was loudly extolled, and from this time onwards the success of gas as an illuminating agent may be said to have been complete. In 1813 Westminster was lighted with gas; in the following year many of the old oil lamps in the streets were superseded by the new light, and in the year after that, as we have just seen, it made a highly successful *début* at Guildhall.

FIG. 2.—A FAMILIAR EXPERIMENT: GAS-MAKING WITH A CLAY PIPE.

The bowl of the pipe is filled with crushed coal and capped with clay; it is then inserted in the fire or a gas jet. The gas issues from the stem, and after a few preliminary puffs will burn with a fairly steady flame.

Its progress now, though still slow, was sure. The old oil street lamps in the metropolis were gradually supplanted by gas, and not many years afterwards its use as a source of light became common in the provinces. Thus its rate of progress became more rapid—everywhere, where men were gathered together in numbers sufficient to maintain gas-works, was the material made and used; and now it is a very small village indeed that does not possess the means of supplying its inhabitants with the wherewithal necessary for the production of the safe, clean, and brilliant gas-flame.

In considering the mode at present in use for the manufacture of this now all but indispensable material, coal gas, it is a point worthy of observation that the main part of the process whereby thousands of tons of coal are daily consumed is essentially the same as that which Mr. Clayton employed when he heated a few chips of coal in a closed vessel by which to charge the bladder from which he burned the *spirit* for the amusement of his friends.

The operations carried out in the production of gas may be said to be two in number:

(1) The distillation of the coal, and

(2) The purification of the crude gas so produced.

The first operation—viz. the distillation—consists in heating the coal in closed red-hot iron or clay vessels, called retorts. We are all aware that if coal be heated to redness in the air a considerable amount of heat and light will result, and that the coal will speedily be burned away and reduced to ashes. We shall not, however, by this process succeed in collecting any such material as coal-gas. If, however, instead of heating the coal in the open air, we heat it in a closed vessel, such as an iron bottle, we shall have a large quantity of combustible gas produced.

This operation, then—that is, heating the coal in closed vessels—constitutes the

first process, or the distillation, as it is called, in the manufacture of gas.

A very simple and familiar experiment will fully illustrate this process of producing gas by the distillation of coal (Fig. 2). Into the bowl of a common tobacco clay pipe are introduced a few chips of coal, about the size of a pea. Upon the top of the coal a layer of clay is put, in order to protect the coal from the action of the air. This simple arrangement being completed, the bowl of the pipe thus charged is heated to dull redness by being placed in the centre of a common fire. In a few minutes distillation of the coal will commence. Smoke will issue from the stem of the pipe, and in a few seconds more this will be succeeded by gas, which, on the application of a light, will burn with a bright yellow flame, which will continue as long as the supply of coal in the bowl of the pipe lasts.

In gas-works, instead of tobacco pipes, huge iron or clay retorts are employed, in which are distilled several hundredweights of coal at each charge. These retorts are built into brickwork, and are heated to the requisite temperature by means of furnaces appropriately arranged. The retorts themselves are nothing more than plain cylindrical vessels, from six to eight feet long, by about eighteen inches in breadth, closed at one end and open at the other. To the open end is adjusted a nicely fitting door, fitted with a powerful hand screw, by means of which the orifice can be quickly and securely closed. Not far from the open end of the retort there is an opening in its upper side, into which an iron exit-pipe is fixed, which is for the purpose of carrying off the gas as it is produced in the retort. All being ready, the retort is heated by the furnace just mentioned until it is red-hot; the door is then opened, and the charge of coal—broken into pieces a little smaller than a man's closed hand—is introduced as rapidly as possible, spread evenly over the surface of the retort, and the door quickly closed. An air-tight joint is made by lining the edge of the lid with well-worked-up lime mortar. This must be quite free from lumps, or an escape of gas results.

Distillation at once commences, and the gas so produced, having no other means of escape, passes up the exit-pipe just referred to, and then into a large iron vessel, named the *hydraulic main*, where it deposits the greater part of the tar and the ammonia water which are produced simultaneously with the gas, and which accompany it thus far in the process of manufacture.

After leaving the *hydraulic main*, the gas—now partially but by no means perfectly purified—passes on to an apparatus called the *condenser*. This consists of a series of iron pipes generally placed perpendicularly, so as to present as much surface as possible to the cooling action of the air. The gas by passing through this condenser is lowered considerably in temperature, by which treatment it is freed from the last traces of liquid impurity with which it may be contaminated. It is not yet, however, free from all contamination; it still contains a certain amount of sulphur, present in the form of two compounds of that element, known to chemists as sulphuretted hydrogen and carbon disulphide. To remove these highly objectionable substances the gas is first passed through an apparatus called the *scrubber*. Here it is made to ascend through a cylinder of broken coke, upon which a shower of water is occasionally played, which removes in great part the compounds soluble in that liquid.

The gas, however, is not yet pure enough for use, and to effect its final purification it is passed through what is known as the lime purifier. This consists essentially of a large, air-tight vessel, in which are placed a number of

perforated trays filled with slaked lime. The gas is thus brought into contact with a very large surface of lime, by the action of which it is freed from the remaining sulphur impurities, and, being now fit for use, it is passed into the gas-holder, whence it is forced to the different points where it is to be consumed.

By reference to the illustration below (Fig. 3), which shows the arrangement of the different pieces of apparatus just described, no difficulty will be experienced in tracing the course of the gas from the point where it is generated in the retort to its final reception by the gas-holder. On the extreme right the retort, heated by the fire beneath, and properly charged with coal, is shown. The impure gas here produced passes up through the exit tube A into the *hydraulic main*, where the tar and other fluid matters are deposited, as already described. It then passes down through the tube B into the upright pipes marked "condensers"; from these it passes to the *scrubbers* and lime purifiers, and finally into the gas-holder, where it is stored for use.

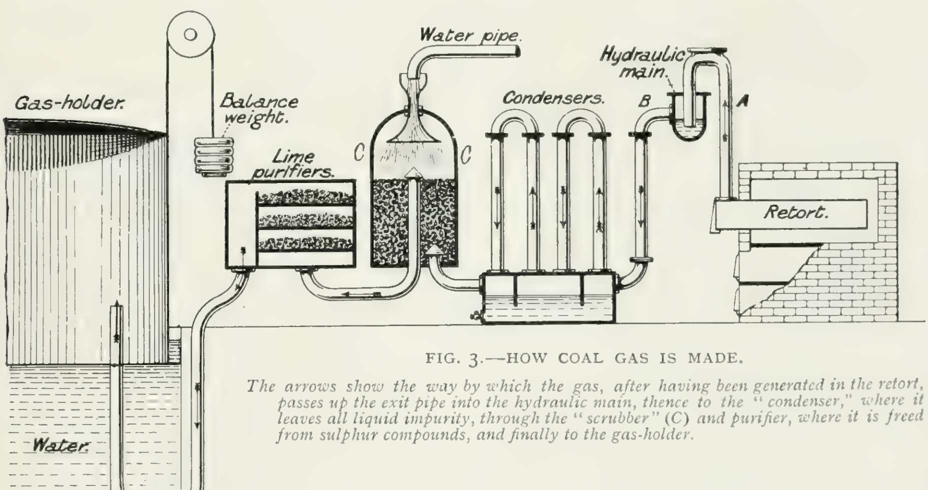


FIG. 3.—HOW COAL GAS IS MADE.

The arrows show the way by which the gas, after having been generated in the retort, passes up the exit pipe into the hydraulic main, thence to the "condenser," where it leaves all liquid impurity, through the "scrubber" (C) and purifier, where it is freed from sulphur compounds, and finally to the gas-holder.

Having now obtained our gas pure and ready for consumption, it seems meet that we should make ourselves acquainted with its composition and with the way in which it acts as an illuminating agent.

Coal gas, as it is usually prepared, contains four or five elements, but of these only two are really useful. These two are—hydrogen and carbon, a familiar form of which is common wood charcoal.

These two substances have very different properties, and neither of them singly would make a good illuminating agent. In consequence, however, of one of them possessing, to a very marked extent, those peculiar properties in which the other is deficient, they, when in combination, constitute a substance which, as we know, fulfils this office admirably.

Coal gas being really and truly a gas, it is difficult at first for a non-chemical mind to conceive how such a substance as carbon or charcoal can enter into its composition. That it does contain this element, however, we can easily show by performing the very simple but convincing experiment of holding a cold white plate in a common gas-flame for a few seconds, when it will be blackened, or smoked as we say. This smoke is nothing more than a portion of the carbon which the gas contained, and which was deposited on the plate in consequence of our having cut off the supply of air necessary for its

combustion, and so preventing its removal in the ordinary way. The presence of the hydrogen can also be shown by holding a cold *dry* glass, such as a tumbler, over a small gas-flame, when in a few seconds the interior surface of the glass will become covered with a thin film of dew or moisture. This film is water, and, as we know that water is generated when hydrogen is burned in air, we have here a proof of the presence of that substance in the gas.

Next we have to consider the offices which these two substances, hydrogen and carbon, fulfil by their presence in coal gas. Hydrogen, as we have seen in a former paper, is a very inflammable gas. It burns very easily, but its flame, though possessing a very high temperature, gives very little light; so feeble, indeed, is it, that it can hardly be seen in broad daylight. Clearly, then, it would not do for illuminating purposes. The carbon, on the other hand, does not burn readily, but when it is heated up to a high temperature, such as that possessed by the hydrogen flame, it becomes incandescent, and gives off a great amount of light. When coal gas burns we may regard these two operations as taking place. The hydrogen being very inflammable, easily catches fire, and, by the great heat which it produces in burning, raises the carbon to such a temperature that it becomes highly luminous, giving rise to the beautifully bright flame with which we are all so conversant.

With reference to the amount of light which is produced when coal gas is burned, this, we find, varies considerably according to the quality of gas which is being burned, and its quality depends to a certain extent upon the mode of manufacture, but much more on the nature of the coal from which the gas has been procured. Thus, the average quality of London gas, which is made principally from English coal, gives a light which is equal to about that shed by fifteen sperm candles, while Edinburgh gas, which is made from a very rich variety of coal found in Scotland, and known as *cannel* coal, gives a light which is nearly twice as strong as that obtained from London gas. This fact is expressed technically in candle power. Thus, until recently, London gas was 15 candle and Edinburgh 30 candle power. The rate at which gas is burned in making the trials necessary to determine its illuminating power is five cubic feet per hour, and the flame so produced is very accurately compared by means of suitable apparatus with the flame of a sperm candle burning at the rate of 120 grains per hour. So that when we say that a certain gas is of 20 candle power we mean to express the fact that the flame produced by burning this particular gas at the rate of five cubic feet per hour gives as much light as that which would be given off by twenty candles, each burning at the rate of 120 grains per hour.

In considering the uses of gas there can be no doubt whatever that the service it renders as an illuminating agent is by far the most important. It furnishes us with a source of light which is at once highly efficacious, extremely convenient, and, when properly used, perfectly safe. From nothing else with which we are acquainted can we obtain a light so handy and so cheap as that which we get from gas.

When, in 1879, the suitability of the electric light* for illuminating purposes was established, shareholders in gas companies were rather perturbed. They were afraid that the days of gas as an illuminant were numbered, for what could stand before the glorious electric light? As a matter of fact, electricity has so far done little to supplant coal gas, and

* The electric light will be treated upon in the series of articles included under the title "The Wizard Electricity."

two reasons for this may be adduced. The first is the cost of electric plant; the second, the introduction of the incandescent mantle fittings for burners as typified by the Welsbach and the Kern. The electric standards are gradually taking possession of London, however; while in big private mansions electricity has been a pet for years, and it is practically only the cost of production that hinders. The "incandescent gas burner" (Fig. 5) is, however, going strongly, and the gas supply be stopped at the meter, and the windows and doors opened to allow what gas has accumulated to escape *before* a light is made use of, no explosion can possibly take place. Instead, however, of this very simple precaution being adopted, we generally find that when escaped gas proclaims its presence in a house the first movement upon the part of the inmates is to search for the leak with a lighted candle. The result is at least decisive.

Photo: Cassell & Co., Ltd.

FIG. 4.—A WARM CORNER: DRAWING THE EXHAUSTED CHARGES BY HAND FROM THE RETORT IN THE SOUTH METROPOLITAN GAS COMPANY'S WORKS.

economy in the amount of gas burned and the steadiness and brilliancy of the light are its strong points.

On the score of safety few gaseous inflammables can compete successfully with gas. It is true that occasionally we hear of disastrous effects arising from explosions of gas. Such results, however, spring almost invariably from gross carelessness. Gas by itself will not explode; it is only when it is mixed with a certain proportion of air that it becomes formidable as an explosive agent; and if, when an odour of gas is perceived in a house,

Besides being useful as a source of light, coal gas is now very extensively employed as a heating agent, being almost universally used in chemical laboratories and other scientific workrooms for this purpose. It is also largely employed by different artificers as a ready and clean source of heat, and it is very frequently used to supply the heat necessary in cooking operations. Some very particular persons aver that food cooked in a gas-heated oven is tainted; but, if the taint exists other than in fancy, its cause is to be sought for in errors of management.

It commends itself for all these purposes by its exceeding cleanliness, there being no smoke and no dust when it is employed as fuel. It is also valuable in so far as it is thoroughly under command—we light our gas-fire and it is ready for use immediately, and when we require it no longer we can extinguish it at once and completely.

Besides, however, serving as a source of light and heat, gas is also used as a motive-power, being applied for this purpose through the medium of the highly ingenious gas-engine. To understand how these elegant machines perform work, we recall to our remembrance the great force which a mixture of gas and air exerts when it is exploded.

FIG. 5.—AN INCANDESCENT BURNER.
This is more economical of gas than the ordinary "fish-tail," and gives a far better light.

In the gas-engine this tremendous power, which in some circumstances is exerted in wrecking our houses, is made to drive a piston from one end of a cylinder to the other. The piston being thus kept moving communicates its motion to a crank on an axle on which a wheel is fixed, and thus a rotary movement, which can be applied to drive any machine, is obtained. This engine, it will be noticed, requires neither fire, boiler, nor steam—a very great consideration certainly, in the many situations where motive-power is required, but where, in consequence of limited accommodation, or for other reasons, the presence of a furnace and steam boiler is not desirable. Moreover, the ease and quickness with which a gas-engine can be got into full working order gives it a great advantage over the cumbrous steam-engine. It may be mentioned here, also, that the cooler a gas-engine can be kept the more work will it do.

Very intimately connected with the subject of coal gas, though perhaps hardly forming a part of it, are the numerous and valuable by-products of this now most extensive manufacture.

The principal of these products are coke, ammonia, and gas tar, as it is called. The first, which constitutes the residue left in the retorts after the distillation of the coal is finished, is largely used as fuel. The second—the ammonia—which in a state of aqueous solution is separated from the gas, along with a certain amount of tar, by the *hydraulic main*, is very valuable, and finds a ready sale. It constitutes the base of ammonia salts, sal volatile among others. The third by-product, the tar, is by far the most important. At first this substance was regarded as a nuisance; to touch it was to be defiled, and the sooner and the more completely it was destroyed the better. The researches of modern chemistry, however, have shown this apparently unpromising material to be a perfect mine of wealth. To understand this, it is only necessary to call to mind the magnificent coal-tar or aniline colours, which, as they are now being produced in almost every hue and every shade, are rapidly superseding the older forms of dyeing materials.

The aniline, from which the colours are produced, is made by a somewhat complicated process from the tar. The crude material, as it is received from the gas-works, is first of all submitted to distillation. By this treatment it yields what is known as naphtha. This naphtha, which is a useful material in itself, is

also distilled, by which operation a very light volatile liquid known as benzol is obtained, which is also very useful, quite independently of the part it plays in the process of the manufacture of the coal-tar colours. This liquid is one of the most powerful solvents of greasy matters with which we are acquainted, and hence it is very useful for removing stains caused by grease or oil from such fabrics as would be damaged by the application of soap and water. It is in very general use for this purpose by those people who make a trade of cleaning kid gloves and other delicately coloured articles of apparel.

The benzol being thus obtained, it is converted by the action of strong nitric acid into what is known as nitro-benzol—a substance possessing a very pleasant odour, closely resembling that of the essential oil of bitter almonds, and which is used by confectioners for the purpose of communicating an agreeable flavour to certain of their wares.

The nitro-benzol having been procured, it is submitted to the last operation, which consists in distilling it with weak acetic acid or vinegar and iron filings. By this operation aniline is procured, and from this the well-known colours are prepared.

Finally, when the tar is distilled until no more volatile matter is given off, there is left a black, solid substance known in commerce as asphalt, which is used extensively in the present day in house-building, and in the making of roads and pavements.

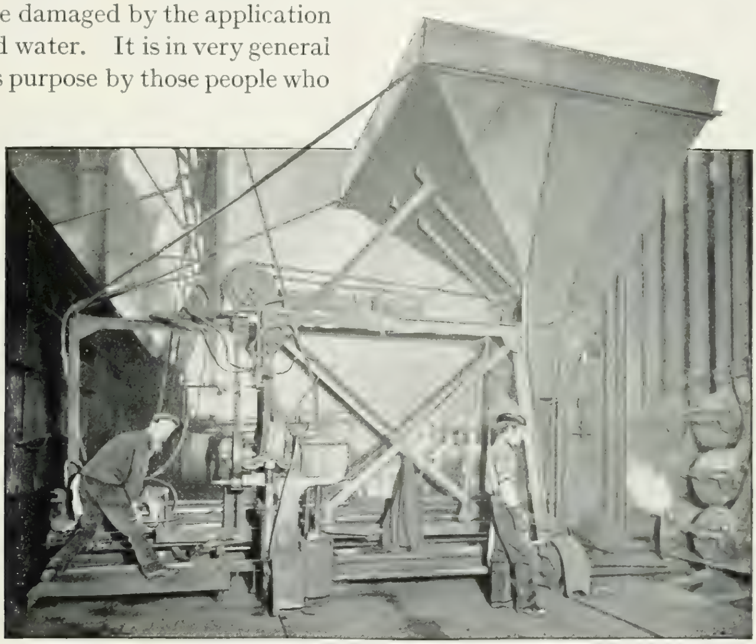


Photo: Cassell & Co., Ltd.

FIG. 6.—UP-TO-DATE GAS-MAKING: CHARGING RETORTS BY MACHINERY.

Thus by the simple distillation of coal we obtain—firstly, the all-important and almost indispensable substance, coal gas; secondly, ammonia, a most valuable product, and one of the greatest importance in modern agriculture and horticulture as a means of artificially supplying plants with the all-important nitrogen; thirdly, coal-tar, from which, as we have just seen, we obtain the useful materials naphtha, benzol, nitro-benzol, and aniline—the source of the coal-tar colours; and fourthly, asphalt, now so much used in house-building and road-making operations.

HOW PLANTS FEED.

By ALEXANDER S. GALT.

THAT a plant to be healthy must be supplied with a sufficient quantity of suitable food is a truth so axiomatic in its nature that there is no need to discuss it. What remains to be seen is what that food is, and how and whence the plant obtains it. What is a *sufficient* quantity is not so easy to decide, for a plant may over-feed itself just as an animal may, and the consequences of this over-feeding are practically the same in both plant and animal. The over-fed one is apt to wax fat and gross, its tissue degenerates, its constitution is impaired, and disease may easily follow; while there is the same tendency on the part of the individual to forget its duties and to remember only that it lives to eat. If any of my readers object to the terms "forgetfulness" and "remembrance" as applied to a plant, I will for the present merely ask him or her to postpone decision for a while until the whole case has been stated.

Photo: Wiele & Klein, Madras.

FIG. I.—A FINE SPECIMEN OF BANYAN TREE.

The aërial roots grow downward until they reach the ground, and then, fixing themselves to the soil, help to support the tree.

Roots are specially connected in the popular mind with the process of food procuring, and therein the popular mind is not wrong. Still, we must be clear upon two points, viz—(1) that a plant does not get the whole of its food through the agency of the roots, and (2) that the roots have other work to do than that of mere absorption, all-important as this is.

We shall soon find that this is true when we look into matters. It is quite a

common saying that an oak tree, for instance, has as much wood below the ground as there is above it. This may not be literally true, but, like most old sayings, it has a substantial basis in fact. The extent of the root system of such a tree is enormous; it must be, else that great

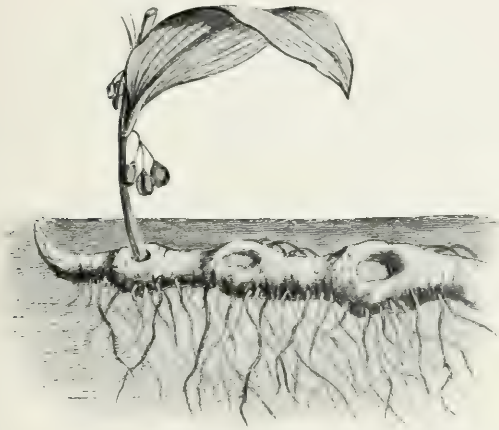


FIG. 2.—RHIZOME OF SOLOMON'S SEAL.

The scars show where leaves and flower stems have been produced in previous years. Note how "feeding" roots are produced on the under side of this rhizome.

head of branches and that stately trunk would be levelled by the first summer zephyr, to say nothing of the blustering equinoctial gale.

The functions of the roots are, then :—

(1) Fixation of the plant to the soil.

(2) Food absorption.

(3) Storage of starch and sugar.

Now let us decide as to *what* the food of plants consists of, for that must lie at the beginning of the subject. Until we have settled this we can go no further. There are comparatively few of the chemical elements that have not been found to be present at some time or other in plants, but this presence is more or less accidental, for it is exceedingly probable that they were found in the plants only because they formed a constituent of the soil in which the plants were growing, and not because the roots *deliberately selected them.* This selective power of roots has been frequently discussed, not without profit perhaps, but certainly without leading to a definite conclusion, and the kindest verdict that can be given it is that of "not proven." The reason why will appear presently, when we come to discuss the "how" of feeding. Meanwhile, here is a list of the elements, thirteen in number, that are always to be found entering into the composition of the plant. For convenience of reference these have been put in table form :—

(1) Carbon.	Taken in by the leaves.	These are the essential elements.
(2) Hydrogen.	Taken in by the roots.	These are the essential elements.
(3) Oxygen.	Taken in by the roots.	These are the essential elements.
(4) Nitrogen.	Taken in by the roots.	These are the essential elements.
(5) Sulphur.	Taken in by the roots.	These are the essential elements.
(6) Phosphorus.	Taken in by the roots.	These are the essential elements.
(7) Potassium.	Taken in by the roots.	These are the essential elements.
(8) Calcium.	Taken in by the roots.	These are the essential elements.
(9) Magnesium.	Taken in by the roots.	These are the essential elements.
(10) Iron.	Taken in by the roots.	These are the essential elements.
(11) Sodium.	Taken in by the roots.	These are the non-essential elements.
(12) Chlorine.	Taken in by the roots.	These are the non-essential elements.
(13) Silicon.	Taken in by the roots.	These are the non-essential elements.

To sum the matter up, it will be seen that the roots absorb the whole of the plant's food except the carbon, which is taken in by the leaves. The way in which the leaves do this is in itself a big subject, and will, therefore, be explained in another paper dealing with the work of the leaf. The elements numbered from 1 to 10 are all essential—let one of them be missing, and the organism suffers; those numbered from 11 to 13, although constantly present, are non-essential—they can be eliminated without any appreciable suffering in health on the part of the organism.

We may define the root as "the descending axis of the plant, which fixes the latter to the soil and carries on the work of absorption." Now let us turn our attention to the structure of the roots, and see how far this facilitates the work they have to perform. In some respects roots are alike. They are colourless, in contradistinction to the stem. They bear no buds or leaves: the stem does. They turn downwards and avoid the light, or, in the words

of the botanists, they are *negatively heliotropic;* the stem seeks the light, that is, it is *positively heliotropic.* Just what causes

FIG. 3.—KNIGHT'S WHEEL: VERTICAL POSITION.

their downward turning, or *geotropism* (literally, earth turning), has been food for more than one hot discussion. It is now generally held, however, that the force of gravity is largely accountable, and this view is supported by the fact that if the position of the roots to the vertical be constantly changed, and the effect of the force of gravity thereby nullified, they do not exhibit this tendency to earth turning. Knight's Wheel—so called because Mr. Thomas Andrew Knight was first associated with this method of demonstrating this phase of the subject—is a rotating wheel containing pockets on its periphery. These are filled with soil, and seeds sown therein. The wheel may be fixed upon the banks of a gently running stream in the same fashion as boys are fond of placing toy water mills. It is found that, when the seeds germinate, instead of the roots turning earthwards, they tend to turn outwards from the centre, as shown in Figs. 3 and 4. No matter whether the wheel be fixed horizontally or vertically, the result is the same.

With regard to origin, roots may be either *primary* or *secondary* (adventitious). Many plants have both. To make clear what is meant by a "primary" root we may turn to a germinating mustard seed, or, if that is too small for easy manipulation, to a broad bean which has commenced to grow. By comparing the seedling with the embryo of the seed it is easy to see that the primary root is a direct continuation of the radicle or miniature root in the embryo. This can be easily seen, and without any artificial aid to the eyesight, in the bean.* The hair-like projections, also shown upon the root-tip at Fig. 9, are the root hairs, of which more anon. It may easily happen that the progress of the primary root is from some cause or other arrested, and in that case secondary or adventitious roots spring from just above the stump. The rhizome (really a more or less under-

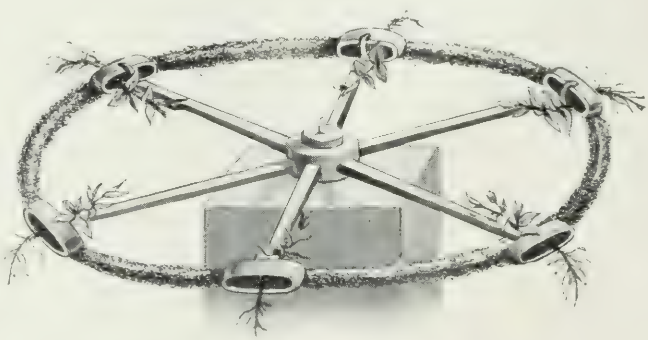


FIG. 4.—KNIGHT'S WHEEL: HORIZONTAL POSITION.

ground stem) of Solomon's Seal, in Fig. 2, is carrying a quantity of secondary roots. The buttercup (Fig. 6), beloved

* The bean should be soaked in water for twenty-four hours when it can be dissected easily.

of botanists as affording an excellent subject for demonstration, has also its full share of these "fibrous" secondary

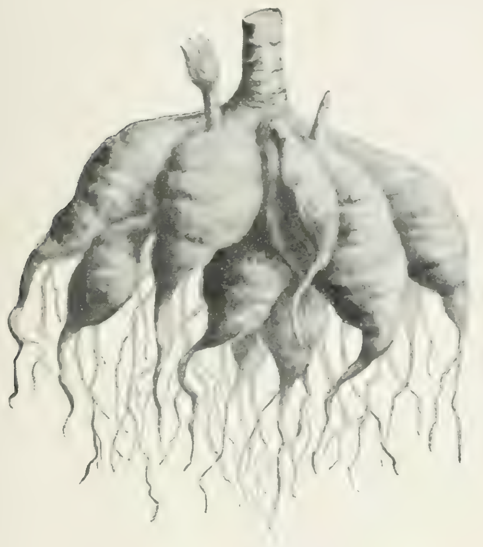


FIG. 5.—TUBEROUS ROOT OF THE DAHLIA.
Here the roots have added storage of food to their other functions.

roots. Examination of the roots of the wheat, and grasses generally, will show that the growth of the primary root has been arrested in their case. The same thing holds good with bamboos, which may be called giant grasses. Sometimes one primary root will persist during the whole life of the plant, will develop into what is technically known as a *tap-root*, and will take upon itself various shapes. It may thicken to become either a thick, conical affair, as in the carrot and parsnip, or fusiform or spindle-shaped, as in the beet-root ; or it may swell out until it is oval or nearly spherical, as with the radish and turnip. Here we have instanced the third function of the root, for it has in these cases become a storehouse, wherein the plant has deposited its accumulated stores of sugar and starch. These stores are destined to be drawn upon in the following year, when flowering and fruiting takes place, for the garden parsnip and carrot are biennials, and have been taught to postpone their flowering until the second year. Unfortunately for their laudable intentions, however, the gardener cuts these aspirations short by consigning the whole lot to the "pot." A familiar example of a "storehouse" root appears at Fig. 5 in the shape of the tuberous root of the highly developed dahlia.

In examining the root system of any woody plant, say one of the popular chrysanthemums, we notice at the outset two sets of roots, as it were — the large main roots, and the small wiry, fibrous ones. If we liken the former to the mains, which conduct the gathered food wherever it is required, and the latter to the feeders, which gather the food in, we shall not be far astray. All roots commence by being active feeders, then they get promoted with age to be the main channels of supply, and the work of "gathering in" is left to the smaller fibres. To understand why this is so we must look a little closer at the structure of the young root. It will be noticed that a number of processes stand out from the branches. These are the "root hairs." To the botanist they are simply single cells, rather elongated, pushed out from the covering layer. To the plant they are of the utmost importance, for they do the actual work of absorption. Root hairs are only to be found on young roots, and sometimes only on the younger portion of these. The older roots have lost them, and then it is that they become mere channels or main drains.

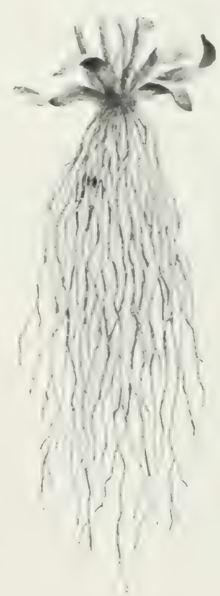


FIG. 6.—FIBROUS ROOT OF BUTTERCUP.

Now, all the substances enumerated in the table, with the exception of carbon,

must first be dissolved in water before they can pass into the economy of the plant. The food solution passes through the closed membrane of the cell wall, and the process by which it does this is called *osmosis*. We may define *osmosis* as

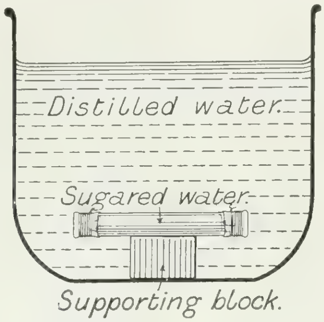


FIG. 7.—THE PRINCIPLE OF "OSMOSIS."

The glass tube filled with sugared water is plunged in a vessel of distilled water. Note the condition of the membranes when the tube is first immersed.

the tendency which two fluids of different densities, separated by a closed membrane, have to pass through that membrane and commingle. The principle of *osmosis* can be demonstrated by the beginner quite easily. Take a glass tube of fair diameter, close one end of it with a piece of bladder tightly fixed, fill the tube with sugared water, and close the other end in the same way as the first. Place the whole in a basin of distilled water, and note the gradual distension of the closing pieces of bladder at the ends of the tube. A distinctly sweet taste will after a time be apparent in the water of the basin, thus proving that a connection has been established between the "two fluids of varying densities" (*see* Figs. 7 and 8). *Osmosis*, thus, has two phases—viz., *endosmosis*, the passage of the outside liquid inwards; and *exosmosis*, the passage of the inside liquid outwards.

Both these phases are concerned in root absorption. By *endosmosis* the plant takes in the substances which are dissolved in the water with which its root hairs come into contact; by *exosmosis* it excretes a little acid, which helps to render the various salts in the soil from which it draws its essentials more soluble. A capital demonstration of *exosmosis* is forthcoming in the case of marble which has been covered with ivy; the delicate tracery of the roots can be distinctly seen. Their pattern thus imprinted on the face of the marble may be, in a measure, caused by discolouration; that this is not the whole of the truth can be at once ascertained by passing the fingers over the affected portion of the stone, for the ridges and hollows are plainly perceptible. It is true that the aërial "roots" of ivy are not real roots, but may more correctly be regarded as aids to climbing. Still, they excrete acid in the same way that roots do, and it is probable that they do this to enable them to get a better grip of the surface.

From what has been said it will be apparent that the process of absorption is purely a mechanical one. The tube full of sugared water could not be said to select the distilled water surrounding it, for it only absorbed in obedience to the workings of the mechanical law. So, too,

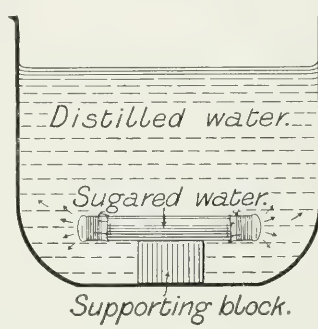


FIG. 8.—THE PRINCIPLE OF "OSMOSIS."

The membranes closing the tube are now distended and the water in the basin has a slightly sweet taste. Communication "between two fluids of different densities" has thus been set up, and it has been made through the closed membrane.

the roots, as far as absorption goes. Whatever is present in the soil in soluble form that they must take in, and the proportion of each element to the other will be very nearly the proportion which each bears to the other in the soil. It is probable that some sort of power of selection is dis-

played by the organism, once the substances are safely inside, as to the use to which they shall be put ; but that is quite another matter. That little or no selective power is possessed by the root hairs is to some extent demonstrated by the fact that plants can and do eat too much of things which are of little use to them, and that they can be poisoned by offensive substances, such as, for instance, strong brine or an over-dose of some chemical fertiliser. Weed-killer applied to walks will just as surely kill the grass or the box-edging if it is brought into contact with them as it will the weeds.

For a long time much was made of the theory that by analysing the *ash* of plants —that is, the incombustible matter that remains after the volatile constituents have been driven off—and noticing the proportions that each ingredient bears to the other, a key might be obtained to the substances most necessary to the welfare of the living plant. Thus, if potassium were strongly marked, a potassic manure should be given ; if phosphorus, then a phosphatic manure, and so on. Even now the view that this is true obtains in some quarters. A little consideration will teach us that the position is untenable—(1) and perhaps the most crucial test of all, the theory does not square with practice ; (2) it is founded upon what is more or less of a fallacy, viz. the selective power of absorbing roots.

It will be evident to all that the tips of the delicate fibres must be soon worn away by being continually pushed through the stones and soil. Nature came to the same conclusion long ago ; hence she was careful to provide each rootlet with a " cap " or tip, and this, as fast as it is worn away, is replaced from within by the mass of actively dividing cells behind. The presence of this root-cap is one of the fundamental differences between stems and roots. Fig. 9 shows this root-cap considerably enlarged. The soft tissue of this " cap " forms what is known as the *spongiole*. Formerly these spongioles were regarded as the organs of absorption. They were spoken of as little mouths through which the plant took in its food. In modern times the centre of attraction has shifted from the spongioles to the root hairs, and the poor spongiole is relegated to its proper place. Both spongiole and root hairs, it will be noticed, are to be

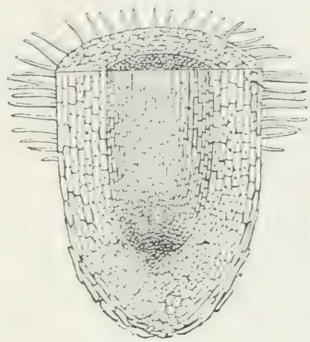


FIG. 9.—A ROOT TIP.

As fast as this is worn away by contact with the stones and earth through which it is pushed, it is renewed by the actively growing tissue inside. Note the root hairs, which are the active feeders of the root.

found only on young roots, which have thus been always regarded, and rightly, as the " feeders."

The reader will now be inclined to ask, " If the selective power of roots does not hold, and the theory concerning the ash being an index to the requirements of the plant is to be condemned as a fallacy, how is it that we arrive at the conclusion which the table has given us, viz. that thirteen elements are constantly present, and that ten of them are essential to the well-being of the organism ? " This state of knowledge has, in truth, only been arrived at after many experiments in what is known as " water culture." The various substances have one by one been dissolved in distilled water, and plants have been grown in them, their behaviour being carefully noted meanwhile. Plants do not take up their food whilst it is in the element stage ; they have to wait until these elements are fused, so to speak, into various more or less soluble compounds before they can draw upon them for support.

A food solution recommended by some authorities consists of:—

Water	1,000 cubic centimetres.
Potassium nitrate	1 gram.
Sodium chloride	5 grammes.
Calcium sulphate	5 ,,
Magnesium sulphate	5 ,,
Calcium phosphate	5 ,,
Iron chloride	a trace.

A solution such as this contains all that is necessary to the plant, and healthy specimens can be grown in it.

FIG. 10.—A MANGROVE (*RHIZOPHORA*).

It has not yet developed the aërial roots which characterise the older plant when growing wild. This specimen is growing in the Royal Botanic Gardens, Kew. Compare it with the mangrove in the swamp, shown in Fig. 11.

Taking now the various substances named, we will inquire into the work which they are supposed to do in the economy of the plant.

Carbon, which, as has already been observed, is taken in by the leaves goes to make nearly a half of the whole weight of the dried plant; it is an essential ingredient in the framework, to which the name of *cellulose* has been given. The wall of each cell and vessel—and the plant is made up of cells and vessels—is composed of *cellulose*. Carbon also forms an important part of the other carbo-hydrates, *e.g.* sugar and starch.

Hydrogen is also necessary to the making of cellulose, and water, which forms so large a proportion of the *green* plant. The same may be said of oxygen; with the addition that by weight oxygen is, next to carbon, the largest constituent of the dried plant.

Sulphur. The use of this is rather vague at present. All that is known is that it is always present in protoplasm. Sulphate of calcium is the salt from which the plant generally gets its sulphur. Phosphorus is usually obtained by the plant from phosphates of lime. Its exact use is not determined, but experiments have conclusively proved that it is essential. The plants will live, after a fashion, without it, but only in a very half-hearted way, and they invariably present a stunted, miserable appearance as long as the phosphorus is withheld. It is believed that this element is a vital ingredient in protoplasm, and that it not only goes to build it up, but assists in its transference from place to place as is required either for repairing old tissues or for making new ones to replace the old.

Nitrogen is the great agent in promoting the growth of leaf and stem. Plants cannot, as a rule, take advantage of the free nitrogen

which surrounds them in such boundless supply; they must wait until by the aid of various bacteroids present in the soil, to which the name of *nitrifying bacteria* is applied, the element is worked into various salts, the chief of which are the nitrates. If these salts are not present, the poor plants may actually starve in the midst of plenty. Although it is so important a substance, nitrogen does not form more than 3 per cent. of the weight of the dried plant.

Potassium, in common with both calcium and magnesium, is necessary to the proper performance of the process of assimilation—namely, that by which the plant obtains its carbon, as will be made clear in a subsequent article. A supply of potash is essential to the formation of starch by the chlorophyll corpuscles. Kainit, sulphate of potash, and phosphate of potash are a few of the salts that are applied to the soil in which crops are growing, when it is wished to replenish or augment the supply of potash. Ordinary wood ashes form another favourite source of supply.

Iron is the great colouring agent in nature. Without it there would be no rosy cheeked apples, no rich hued tomatoes, and none of the wonderful colouring exhibited by the leaves of so many of our cultivated plants. As far as plants are concerned we are in the middle of the "iron age," and there is no immediate prospect of a change.

It has been already noted that plants cannot, as a rule, absorb free nitrogen, but have to wait until it is in the form of nitrogenous salts, *e.g.* nitrate of soda and sulphate of ammonia. The members of the great natural order *Leguminosæ*, the pod-bearers, form a notable exception to the rule. These plants are subject to the attacks of a certain minute organism (*Bacillus radicicola*), a member of the *Schizomycetes*, or fission fungi, which forms small corns or nodules upon the roots. By the aid of these bacteria the plant is enabled to make use of the free nitrogen of the atmosphere, and, in fact, to leave the ground in which leguminous subjects are growing richer in nitrogenous salts than it was previously. With all other plants the exact reverse is the case, for they draw upon the stores of available nitrogen (*i.e.* nitrogenous salts) in the soil, and in time, if no manuring were done and if the crops were steadily removed, would exhaust it of this item of plant food, seeing that the natural process of nitrification would be too slow to keep pace with the demand for soluble nitrogenous salts.

That leguminous plants enrich the soil in which they are growing to the extent of adding to the nitrogenous compounds it contains has been known for years. The Romans were well aware that this was the case with regard to clover. The collective name of *nitragin* has been proposed by Professor Oliver Nobbes for the nitrifying bacteria which live upon the roots of leguminous plants, and the term is occasionally seen used. In some respects it is an unfortunate one, from its close resemblance to the word nitrogen, the element; but, at least, it is a constant reminder of the vital connection that there is between *nitragin* and *nitrogen.*

The phenomenon of the one organism, a bacillus, living upon the roots of another plant, the pea or bean, and actually helping it to carry on its vital processes, is known as *symbiosis.* It will be observed that these *nitragin* are in no sense of the word parasites, since a true parasite takes all it can get from its unlucky host and gives nothing in return. The *nitragin* may be likened to lodgers who help to pay the rent of the house, and, moreover, they are lodgers whose rent is never in arrears—they are, in fact, quite model sub-tenants.

The fact that legumes generally are able to make use of free nitrogen is taken advantage of in all scientific systems of artificial plant feeding or manuring, and yet it is to be feared that there is still a vast amount of ignorance on the subject to be

met with — accompanied, of course, by some prejudice against knowledge of this kind.

Theoretically, there seems no reason why other plants than the legumes should not offer shelter to nitrifying bacteria. Possibly this may be one of the developments of the future; it would be a distinct gain, seeing that it would do away with all prospect of the promised nitrate famine.

FIG. II.—A CLUMP OF MANGROVES (*RHIZOPHORA*).

These curious swamp-loving plants are some of Nature's principal agents in the work of reclaiming land from the sea. Their roots are continually being pushed further out into the water, and catch and hold vast quantities of vegetable débris, which by-and-by becomes comparatively solid land. Even the seeds of the mangrove have a way of their own, for they germinate whilst yet on the parent tree, and do not drop into the water until they are furnished with leaves and roots, and are ready to start the battle of life for themselves.

A PIECE OF ROCK SALT.

THOUGH man derives his chief supply of food from the animal and vegetable world, there is one condiment that is considered necessary to his existence for which he is indebted to the mineral kingdom. That is salt, chemically chloride of sodium, or sodium chloride, a substance abundantly distributed over the greater part of the earth, and stored in untold quantities in the waters of the ocean. If we look at a piece of the mineral in its rock form, we shall find that it is almost as heavy as a bit of sandstone of similar bulk, resembles alum in hardness, and is of a dirty red colour, streaked with transparent white veins. We might have chosen a purer sample, but the impurity gives us an opportunity of explaining that only a small proportion of the beds of rock salt which have been opened up have been found free from an admixture of foreign substances. Were we to analyse this specimen, we should find that its colour and dulness are due to the presence of iron-rust, sulphate of lime, and probably some clay. Other samples might differ in colour, and yield potassium chloride, calcium chloride, and magnesium chloride. Even in the refined salt some of these substances are present, but in minute quantities. The crystalline structure of salt is almost obliterated in the rock form, and, if we chip off a piece, it will be observed that it presents a foliated or fibrous texture. The outside of the lump is moist to the touch, owing to the affinity for moisture of some of the alien ingredients. Pure chloride of sodium retains a perfectly dry surface, and a remarkable property it possesses is that of freely allowing the passage of heat rays. Of 100 rays of heat a slab of clear rock salt will transmit ninety-two, while plate glass transmits only twenty-four, and clear ice none at all. This fact is of great value to the scientific experimentalist.

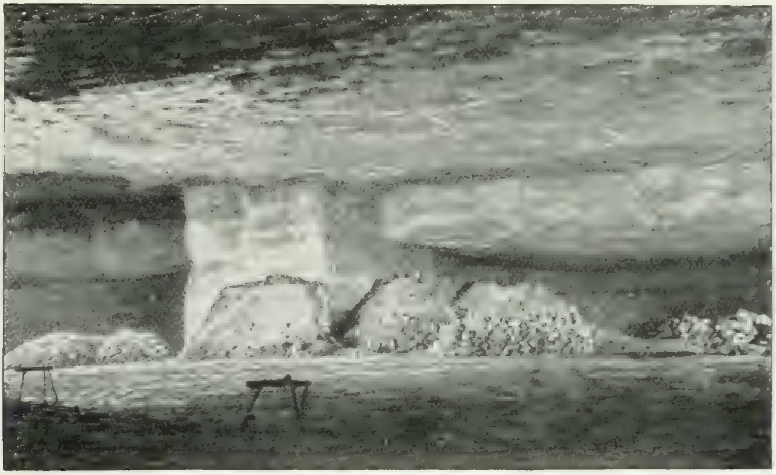


Photo: T. [illegible], [illegible].

FIG. I.—INTERIOR OF MINE AT NORTHWICH, SHOWING COLUMNS OF ROCK SALT.

Deposits of rock salt occur in various parts of Europe, the most extensive and best known on the Continent being in the

province of Galicia, in Austria. The salt mines at Wieliczka are not only the most famous in the world, but they are also among the oldest, for they have been worked continuously since the thirteenth century. The greatest depth is not far short of 12,000 feet, while the tunnellings extend for six miles from east to west, and two miles from north to south. Transport is obtained by some thirty miles of tramways (Fig. 5). Wallachia, Hungary, Salzburg, and the Tyrol have all flourishing salt mines. Coming to rock salt deposits in this country, we find that the Cheshire beds in the basin of the River Weaver have been worked for many years. The beds at Northwich (Figs. 1 and 2) are found between 200 and 250 feet below the surface. In the same county, there are substantial salt beds both at Wheelock and Winsford. At Stoke Prior and Droitwich, in Worcestershire, there are other considerable deposits, brine being found in both cases. The Lancashire salt beds have only been discovered recently—or, at least, they have only lately been turned to account, for Preesall brine was not worked until 1890. In the same year 159,000 tons of rock salt were mined in England, while 1,958,000 tons of the popular commodity were obtained from brine.

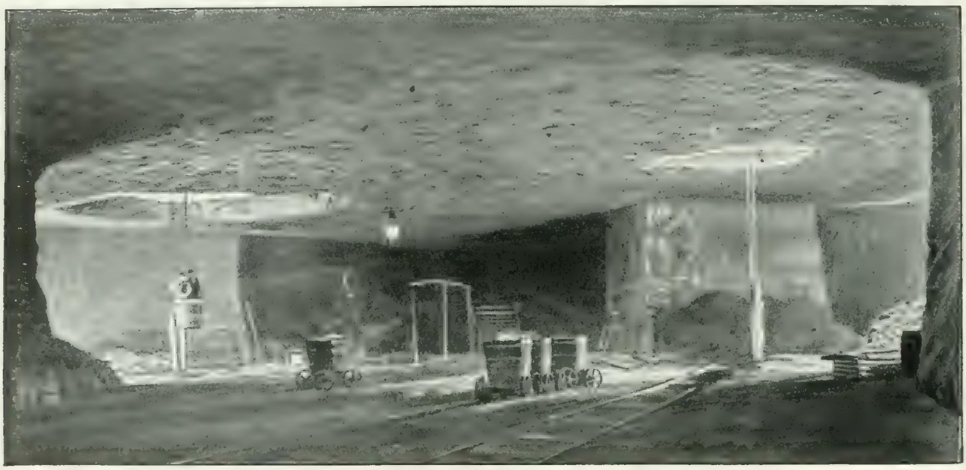


Photo: T. Birtles, Warrington.

FIG. 2.—INTERIOR OF ROCK SALT MINE AT NORTHWICH, LIGHTED BY ELECTRICITY.

Note the rails upon which run the trucks for conveying the mineral from the galleries to the shaft mouth.

Where have these deposits come from? Geologists have long puzzled over this question, and even yet they are not quite agreed on the matter. Some attribute them to volcanic agency, but the bulk of testimony appears to be with those who assign to them a watery origin. They do not belong to any particular geological period, for while the deposits existing at Wieliczka are in the formations of the Tertiary epoch, those in Cheshire and the Austrian Alps are Triassic, whilst borings in Permian deposits have been made in the neighbourhood of Berlin to the depth of 4,000 feet. The strata of the Carboniferous era furnish brine springs in Northumberland, and also in Michigan and Virginia, whilst those in the vicinity of Lake Huron are from Upper Silurian formations.

In proof of the theory that the salt was precipitated from water surcharged with saline matter, it is pointed out that this process is now going on in the case of the Dead Sea, the Caspian, the Sea of Aral, the great salt lake of Utah, and

other land-locked bodies of salt water, in all of which salt is being deposited.

But we must return to the great saliferous beds that underlie the valley of the River Weaver in Cheshire, the chief source, not only of the salt used as food, and in the chemical manufactures of this country, but of much that is consumed in other parts of the earth. The Cheshire field has an area thirty miles in length and from ten to fifteen miles in breadth, and at its richest part it contains two great layers of rock salt, the upper of which is from eighty-four to ninety feet in thickness, and the lower from ninety to 170 feet. Over this great mass of mineral stand the towns of Northwich and Winsford, the chief seats of the salt industry. It was only in 1670 that the mineral in this locality was discovered, though salt was made from the brine springs and pits from time immemorial—before the dawn of the Christian era, in fact.

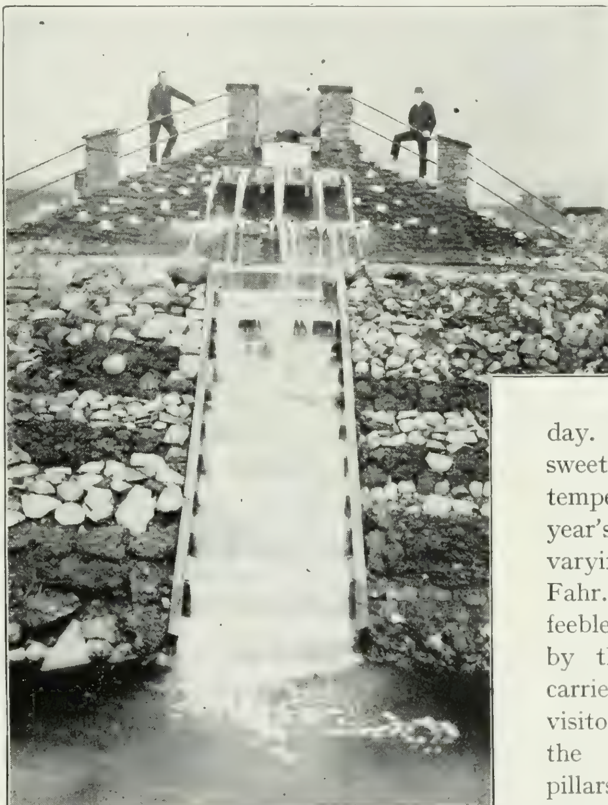


Photo: T. Ernest Leigh, Winsford.

FIG. 3.—BRINE RUNNING INTO CISTERN.

The Marston mine at Northwich—to which visitors are sometimes admitted—is one of the most extensive in the district, and is a highly interesting sight. It has been excavated to a height of sixteen feet over an area of about forty acres. The roof is supported on huge square pillars of the native rock left at regular intervals of about ten or twelve yards by the excavators. Both roof and floor have been cut level, and the latter is covered with a coating of pulverised salt, as dry and as easily disturbed as the dust on a macadamised road on a fine summer day. The air is dry, sweet, and cool, the temperature from one year's end to the other varying little from 53° Fahr. Even in the feeble light afforded by the few candles carried by a group of visitors and their guide, the surfaces of the pillars and roof display most beautiful effects, and at many points appear to be encrusted with gems. The rock is of various hues, passing from deep red to transparent white, with here and there a touch of yellow. An examination of the roof reveals a striking peculiarity in the formation of the salt rock. It appears to be composed of masses of varied figure, and of different sizes, and has the effect of an irregular species of mosaic work. The outlines are in some cases circular, in others oval, but for the most part pentagonal, and the separate forms

measure from two to twelve feet in diameter. The boundary line of each block is composed of a streak of white from two to six inches wide, and inside this the mass generally becomes darker towards its centre. For the delectation of visitors coloured lights are ignited by the guide, who for that purpose removes to a distance of a hundred yards or so. The effect of the light is magical. It reveals for the moment the vastness of the subterranean chamber, and brings out the pillars in full relief. The beauty which even the candle rays enabled one to discover is now intensified a hundredfold; and a person of an imaginative turn of mind might well suppose that he was enjoying the splendour of the scene of Aladdin's adventures. The interior of a typical salt mine is shown in Fig. 1, whilst Fig. 2 gives an idea of the marvellous effect produced when the passages of the mine are illuminated by means of the electric light.

Photo: T. Ernest Leigh, Winsford.

FIG. 4.—MAKING "HANDED" SQUARES OF SALT.

While the mining of rock salt is still carried on in Cheshire, most of the salt of commerce is obtained from brine, which is pumped out by powerful engines and led into the large open tanks or ponds which are an adjunct of the salteries (Fig. 3). In some parts the brine rises to the surface of the ground, but in others it has to be pumped from a depth of two hundred feet or more. The proportion of saline matter held in solution varies to some extent, but for the most part it constitutes 25 per cent. of the total weight of the brine, whereas the saltest sea-water obtainable contains only between 3 and 4 per cent.

The salt is extracted from the brine by evaporating the latter by heat, until a point is reached at which the proportion of water is too small to hold the mineral in solution, and it becomes solidified in the form of crystals. The evaporating pans are huge trays of iron boiler-plate, and usually measure forty or fifty feet in length, by half that breadth, and fifteen or eighteen inches in depth. They are supported on brickwork in which furnaces and flues are constructed. The quality of salt to be produced is determined by the temperature at which evaporation is carried on. Bay or fishery salt, which is very coarse in the grain, is made at a temperature of 110°; what is known as "common salt" at 165°; and "stoved," or fine table salt, at 226°. In the production of two tons of common salt, one ton of coal is consumed; and a pan of average size is capable of turning out two hundred and fifty tons of that quality per week.

By stooping over the pan the process of crystallisation may be seen going on. It begins, as already stated, when the evaporation has proceeded so far that

FIG. 5. VIEW IN THE GREAT SALT MINES AT WIELICZKA, GALICIA.

These mines, which have been worked since the thirteenth century, extend for six miles from east to west and two miles from north to south: they contain about thirty miles of tramways.

there is less water than is sufficient to hold the salt in solution. Little patches of what seems to be semi-transparent scum appear on the surface. These patches are composed of groups of salt crystals which are thus formed on the surface of the brine, and sink when they acquire a certain weight. The crystals are cubical in form; and when the evaporation is conducted rapidly they arrange themselves in a peculiar way, and form conical or "hopper" crystals. The first-formed crystal floats in the brine, in which it makes a depression. Fresh crystals forming near are attracted to this centre, and attach themselves to it — first in one row and so on, until the mass is completed, when it sinks to the bottom and makes way for fresh structures of the same kind. The crystals are allowed to accumulate until the solid matter in the pan is equal to about three-fourths of its contents. In the case of the table variety, the salt is ladled from the pan into wooden moulds, in which it is allowed to consolidate; and on removal from these it is dried in a stove. The coarser salts are deposited on a platform and left to drain for some time, after which they are completely dried in the stove.

Owing to the dissolution of the rock caused by drawing off the brine, extensive subsidences of ground take place at intervals, whereby houses are wrecked, gas- and water-pipes broken, railway and canal traffic interrupted, and patches of valuable land flooded. Loss of life has also been caused. The wharves on the Weaver have had to be raised repeatedly, and, in the lower parts of Northwich, houses and trees have sunk so far as to be surrounded by water. In the town itself it would be difficult to find a bit of wall true to the plummet, or a door or window exactly square. Walls are cracked and roofs "saddled" in every direction, and houses are pointed out which have been twice rebuilt within forty years, while others are miraculously held together by iron stays and other devices. Various plans have been tried to counteract the instability of the ground, the most successful being that according to which the houses rest at the street level on great beams of timber. These beams form, as it were, a second foundation for the houses; and, whenever signs of subsidence appear, the introduction of fresh bricks or wedges between the beams and the masonry beneath them keeps the upper part of the building from being wrecked. So serious is the effect of the repeated subsidences on property that the owners have, on more than one occasion, appealed to the Government to step in and put a stop to the pumping of brine.

At one time a good deal of salt was procured by evaporating sea-water, but this method has fallen into desuetude as far as Great Britain is concerned, the treatment of brine being a much more profitable method. Sea-water is still evaporated, however, in Spain and Italy, and to some extent upon the coasts of Southern France. The name "bay salt" is given to salt thus obtained.

The various uses to which common salt is put, the way in which it is employed in the manufacture of soda (with hydrochloric acid as an important by-product), its use as a condiment and in the manufacture of soap, must form the subject matter for another paper. At present we are only concerned with the way in which it is obtained. We know something, however, of its value, and, although in this country it has never reached such a price as to become currency, as it has in Thibet, we may congratulate ourselves upon the abolition of the salt tax, which for a time kept prices comparatively high. The salt duties were first put into force in this country in 1702; 5s. per bushel was the duty in 1798, and it increased by leaps and bounds until 15s. per

bushel had to be paid. The salt tax was finally abolished in 1825. British "made" salt finds its chief market in India and the United States, and it is estimated that upwards of 300,000 tons are annually exported to the former country.

"Butter and cheese" salt, as it is termed, is fine salt that has not been "stoved," but allowed to dry naturally. When a coarse grain is desired, little heat is employed, and the crystals are suffered to remain for a much longer time in the "pans."

Photo: T. Ernest Leigh, Winsford.

FIG. 6.—WAREHOUSING SALT.

THE MAGIC, OR OPTICAL, LANTERN.

By T. C. HEPWORTH.

THE magic lantern may be described as an optical instrument for projecting the enlarged image of a transparent picture or other suitable object upon a wall or screen by means of a powerful light. The invention of this instrument is ascribed to A. Kircher, a learned Jesuit of the seventeenth century, and in very crude form such a contrivance is figured in his "Ars Magna Lucis et Umbræ." The instrument has been generally regarded as a mere toy until quite recent times; but now so much attention has been lavished upon its construction that it takes its position as a scientific instrument of great value, and one which finds a place in every lecture theatre in the world. It had long been thought that its old title was derogatory to it, and it is now commonly referred to as "the optical lantern," the term "magic lantern" being reserved for the product of the toy-shop. The improvement of the instrument may be traced to several causes, and the first and most important of these is represented by the substitution of photographic transparencies on glass for the hand-painted and necessarily crude paintings formerly in use. It is true that for large instruments of the better class some very beautiful paintings were executed for public exhibition at vast expense; but this kind of glass painting may now be regarded as a lost art, for it has been altogether replaced by the faultless photograph. Another improvement was due to the introduction of powerful lamps burning mineral oil, in place of the argand lamps formerly in use. Now, however, the limelight has been rendered so easy of production that this far more powerful luminant is commonly employed. The electric arc-light is also coming into use for lantern purposes, and at many lecture halls throughout the kingdom, where the current is available for general illumination, special leads have been provided for this particular purpose.

The body of the lantern is generally of box form, and made either of wood or metal. If the former material is employed, it is necessary to give it a metallic lining, with an air space between that lining and the wood, so as to keep the instrument as cool as possible. Even with this precaution the limelight jets in present use are so large, and the heat from them so great, that it is not uncommon for the woodwork of a lantern which has been long in use to take fire. The chance of ignition is still greater when the arc-light is employed, for the heat from the carbon pencils is most intense. A metal casing combined with an asbestos lining is perhaps the best material to use for the lantern, but opticians are so fond of making apparatus look smart, by the employment of polished mahogany and lacquered brass, that it is difficult to make them believe that a plainer mounting would be more serviceable, if not quite so showy. The casing of the lantern is, after all, a minor matter compared with its optical system, under which term is comprised the lenses whose duty it is to project the image of the pictures on the distant screen. This optical system consists of two parts or sets of lenses, one being known as the "condenser," and the other as the "objective." The duty of the former, as its name implies, is to condense the light, from whatever source it comes—mineral oil, limelight, or electric arc—upon the lantern picture, and the office of the latter is to form a magnified image of the picture on the screen. The efficiency of a lantern

depends upon an adequate light and a properly constructed lens system. The relation of the various parts of this system will be readily understood by reference to Fig. 1, where L is the radiant point, C the condenser, P the lantern slide, or picture, and O the objective lens.

For many years little attention was devoted to the quality of glass used for lantern lenses, and the condensers especially were made of glass with a greenish hue. It was also a common thing to employ a single lens, full of faults, as an objective. These difficulties in the way of getting perfect effects on the screen have now been remedied. Mr. Dallmeyer was one of the first to see that the optical lantern was worthy of better things, and he produced condensers made of the best white glass, quite free from all blemishes, and constructed on scientific lines. His objectives, modelled on the photographic portrait lens, are also of fine quality, the light produced on the screen when these lenses are in use being of the greatest brilliancy.

Unless a lantern is to be used in one particular place at a fixed distance from the screen, objectives of different foci will be necessary: the nearer the screen the instrument is placed the shorter the focal length of the objective employed, and *vice versâ*. The objective lens is always held in a telescopic front to the lantern, and by moving this in and out the image can be roughly focussed; but the lens mount is furnished with a rack-and-pinion movement, so that the image can be made perfectly sharp at the moment of exhibition.

It is essential that the lantern should, if possible, be level, and opposite the centre of the sheet or screen; but it is seldom the case that this position can be secured, for in nine cases out of ten the lantern is on the floor, and has to be tipped up at the fore end to properly cover the sheet. As in such a case the lower part of the sheet will be appreciably nearer to the lantern than its upper part, the image will be terribly distorted. The remedy is to slope the sheet so that it squarely faces the lantern, and the fault will disappear.

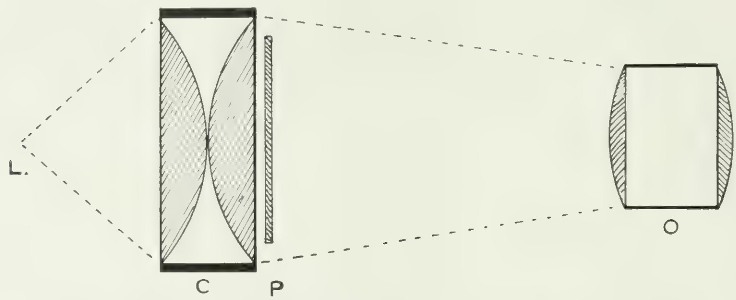


FIG. 1.—SHOWING THE OPTICAL SYSTEM OF THE MAGIC LANTERN.
L. The position of the lamp, jet, or arc light. C. The condensing lens. P. The lantern slide. O. The objective lens.

A sheet is most commonly employed for lantern exhibitions, because at the end of the proceedings it can be readily rolled up and stowed away, but it is by no means the best thing to use. A white-washed wall is *par excellence* the surface on which to show projected pictures to the best advantage, and, after this, a sheet painted with opaque white pigment, which will roll up when not in use. The reason for giving this preference to an opaque surface for lantern work is that when an ordinary calico sheet is used much of the light penetrates it, and is wasted by illuminating the space behind. With a white wall or opaque sheet, on the other hand, none of the light gets through; a little is absorbed, the rest is reflected back to the spectators, and the result is a more brilliant picture. When a very powerful limelight or electric

light is used, and the picture projected is not large, there is so much illumination that a little loss does not matter. It is, however, different when a large screen has to be covered, in which case we must do our best to conserve the light.

There are three descriptions of lime-light lamps in use. First, we have one which employs a spirit lamp in lieu of hydrogen, the stream of oxygen passing through the spirit flame and making the lime cylinder white hot. This is serviceable in out-of-the-way districts where there is no gas supply laid on. Secondly, there is the blow-through jet, in which the two gases, hydrogen and oxygen, do not meet until they arrive at the point of combustion, *i.e.* at the lime cylinder. This jet is shown at Fig. 2. This is a most useful form of jet to employ, especially for private use, for the hydrogen is drawn from the house supply by attaching an indiarubber tube to the nearest gas bracket, and the oxygen only has to be imported. (It may as well be stated here that house gas, carburetted hydrogen, is universally employed for lantern use. There is no advantage, and much expense entailed, in using pure hydrogen.) But to secure the greatest amount of light the mixed jet, Fig. 3, must be the one selected.

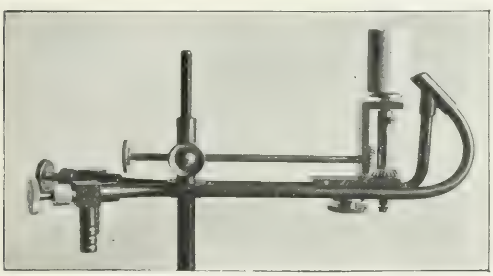


FIG. 2.—BLOW-THROUGH JET, FOR USE WITH OXY-HYDROGEN (LIME) LIGHT.
The lime cylinder lies close to the jet.

In this form the gases proceed by two separate tubes, governed by separate taps, to the mixing chamber just below the jet orifice, and the mixed gases, in one powerful and intensely hot flame, impinge upon the lime cylinder, the pin to hold which is plainly seen in the picture. It will be noted that in these patterns of jets the gas tubes are governed, not by ordinary taps, but by screw valves. This is an excellent arrangement, because the quality of the light greatly depends upon the proportion of hydrogen to oxygen, and this can be adjusted to the greatest nicety by means of these delicate screws. It is always the practice with experienced lanternists to light the hydrogen first, so as to thoroughly heat the lime, the oxygen tap being then gradually turned on until the most brilliant effect is obtained.

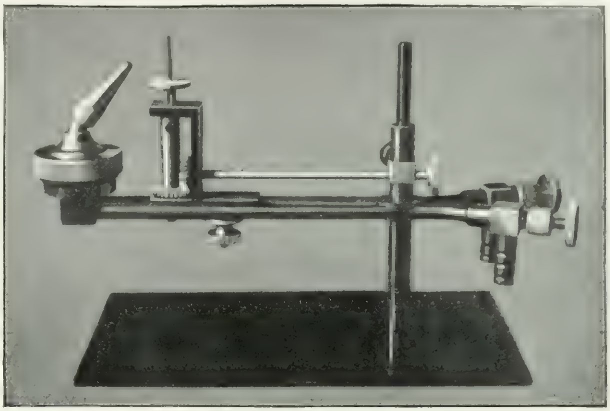


FIG. 3.—MIXED JET.
This gives a better light than the blow-through jet.

It may be noted that the lime pin can readily be turned by means of bevelled gearing from the back of the lantern, while at the same time the distance of the lime cylinder from the jet can be adjusted by means of a set screw below the horizontal tubes which supply the gas. It is most essential that the lime should be at the proper distance from the jet, namely about one-eighth of an inch, and that it should be frequently turned. The action of the flame is to form a pit in the

lime, and, unless the cylinder is turned so as to offer a fresh surface to the jet, that pit becomes enlarged into a little cavern, from the sides of which the flame may be reflected back on to the condenser. Many a valuable lens has been split in this manner, and the tyro is warned against a similar catastrophe.

The mixed jet can also be used for that modification of the limelight known as the ether-oxygen light. In this system a reservoir packed with flannel or cotton soaked in ether is employed, instead of hydrogen, and is connected up with the hydrogen tap on the jet. This arrangement gives a splendid light, but it should be remembered that ether is a dangerous thing except in experienced hands, as it gives off a vapour which will take fire at a distance from the bottle in which it is held. The terrible fire at the Paris bazaar a few years ago, by which so many lives were lost, was caused by the careless use of ether in producing this form of limelight.

When the Drummond or lime light first came into use, it was quickly seen that it was well adapted for the needs of the magic lantern, but the business of making oxygen gas, or rather of separating oxygen from the materials with which it is commonly associated, was an undertaking that was not free from a suspicion of danger. The use of the limelight lantern was, therefore, somewhat limited, and was confined to the large lecture halls. The common method of obtaining oxygen was to heat a mixture of potassic chlorate and manganese dioxide in a retort, when the gas was given off and stored in an india-rubber, wedge-shaped bag. A similar bag was employed to hold the hydrogen gas, and the two bags were placed under pressure between boards heavily weighted. This practice has become quite obsolete since Messrs. Brin showed how oxygen can be separated from the atmosphere, of which it forms 20·95 per cent. (mean), and stored in metal cylinders. For many years it has been the practice to supply dentists with nitrous oxide gas, and carbon dioxide has also been on sale for various purposes, both these gases being contained in strong metal cylinders. When oxygen first became a marketable commodity, it was sent out in wrought-iron containers at a pressure of about 300 lb. to the square inch; but the cylinders were both bulky and heavy. Now, by the use of mild steel, the strength has been so much increased that a cylinder of the size once necessary to hold 10 feet of compressed oxygen or hydrogen will hold 60 feet, while at the same time its weight is much reduced. A cylinder measuring about 6 feet in length and 6 inches in diameter will hold 100 feet of compressed gas at a pressure of no less than 1,800 lb. on the square inch, while the walls of the vessel are only five-sixteenths of an inch in thickness. Now, 1,800 lb. pressure is about twelve times what a railway locomotive boiler has to stand, and looked at in this way a modern gas cylinder seems a dangerous thing to play with. But as each cylinder, before leaving the maker's hands, is tested by hydraulic means to a pressure of two tons per square inch, it will be seen that there is a good margin of safety. Upon one occasion a cart-load of these charged cylinders was being taken along one of the London thoroughfares when a wheel came off the vehicle, and its contents came to grief. The cylinders were shot out into the roadway, and bounced and rolled all over the place, but not one of them was injured in any way. It is not often that charged gas cylinders have been submitted to such a rough and unexpected test.

There was, however, one occasion upon which heavy weights were purposely dropped from a height upon a charged cylinder, in order to see how much the latter would stand. The result showed that it could be deeply dented, but the metal refused to rupture even under the hardest blows.

The writer has watched the entire pro-

cess of manufacturing these cylinders. First a blank of metal like a thick pancake is heated in a furnace, and forced by hydraulic pressure into the form of a cup.

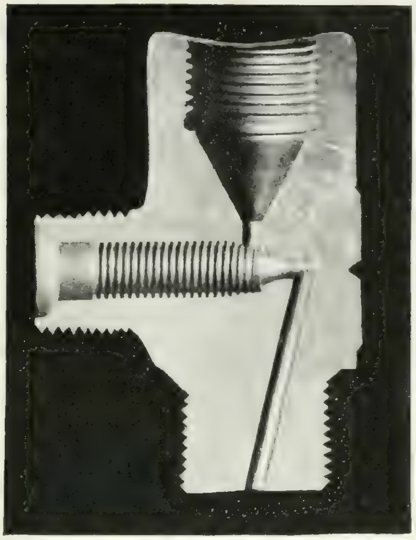


FIG. 4.—SECTION OF A "NOZZLE" CYLINDER.

Each cylinder is calculated to withstand a pressure of two tons to the square inch. The pressure of the enclosed gas when the cylinder is fully charged is 1,800 lb. per square inch.

This cup, by being urged into tubes of decreasing diameter, gradually gets elongated to its proper size, after which the open end is hammered in, and the brass nozzle containing the valve fitted in its place. The greatest care is exercised at every stage of the operation, and this care is by no means diminished after the cylinders come into common use. When such a cylinder is sent to be charged, the firm dealt with will, if necessary, anneal the metal at a very small charge, and this duty is performed from time to time, as is considered necessary.

Another wise precaution which has been introduced is to paint the oxygen cylinder black and the hydrogen one red, all the fittings of each partaking of the respective colour. Another still better guard against accidental admixture of the two gases, which are worse than gunpowder when united, is the provision of a left-hand screw for the hydrogen cylinder, while that on the oxygen cylinder has the usual right-hand thread. Thus the most careless man known would not be able to attach a cylinder to its wrong connections.

The heavy brass fitting which forms the top of one of these cylinders, with its screw connections, is shown in section at Fig. 4. It will be noted that there is a very narrow passage slanting downwards for the gas, and that this can be closed at its upper end by a screw plug or valve, the seating for which is shown on the left-hand of the figure. The cone-shaped opening at the top is where the gas emerges from the cylinder, and this opening has, above the cone, an internal screw, to which certain fittings can be attached when the cylinder is in use.

It will be easily understood that when the tap or valve of one of these high-pressure cylinders is turned on the contained gas escapes with considerable violence, and that the pressure is far too great for the purpose in view. It is therefore customary to use a regulator of some kind, and one of the best is Beard's, which is shown attached to a cylinder in Fig. 5. This regulator consists of a cylindrical rubber bellows which rises when the gas is turned on, but it has within it a "lazy-tongs" arrangement which closes the gas aperture when the bellows rises to a certain height. As the gas is drawn upon the bellows sinks, the aperture is once more uncovered, and the gas again issues. Thus, with this regulator, just so much gas is supplied as is wanted, and no more, and the jet can be served from its own tap as easily as if the gas were

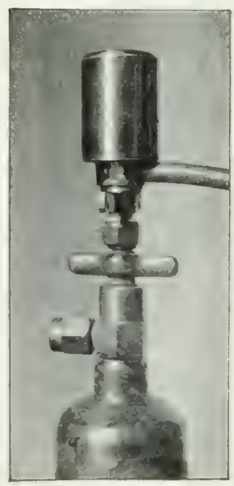


FIG. 5.—REGULATOR ATTACHED TO "GAS" CYLINDER.

contained in a bag, as under the old-fashioned system. It is possible, in the absence of a proper regulator, to serve the jet direct from the cylinder, in which case the jet tap must be left fully open; but this course is inconvenient, and only permissible in experienced hands. Moreover, as the cylinder gradually empties the pressure becomes reduced, and more gas must be supplied by opening the valve, or the light suffers. The regulator, with its protecting cap removed, so as to show the bellows and its spiral spring, is shown at Fig. 6. Under certain conditions, when using the cinematograph attachment to a lantern, for instance, and showing animated pictures alternately with slides, it is advisable to have the means of quickly turning on an increased gas supply without using a regulator. For this purpose the arrangement shown at Fig. 7 is a good one, a screw tap with a large milled head which can be grasped easily in the hand being fitted to the cylinder, as shown. This figure also shows an attached gauge.

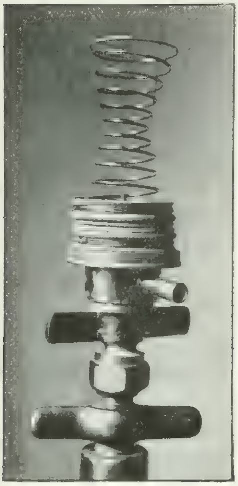


FIG. 6.—REGULATOR WITH SPIRAL SPRING: CAP REMOVED.

It is, of course, quite impossible to see how much gas a cylinder contains, but we can easily measure its contents if we can ascertain the pressure. This can be done by attaching to the cylinder a gauge of the pattern shown. Such a gauge is always found on a steam boiler, save that it is constructed to show far lower degrees of compression. A full cylinder, as it leaves the works where it has been charged, should always indicate on the gauge a pressure of 1,800 lb., *i.e.* 120 atmospheres, and this is the case whether it is a 10-feet, a 20-feet, a 60-feet, or a 100-feet cylinder. Suppose that we are dealing with a 20-feet cylinder, and that it has been in use with the lantern for two hours. If we have been liberal with the gas, possibly one-half of it has gone; and if this be the case, the gauge will mark 60 atmospheres. If it only marks 30, then we may be sure that only 5 feet of gas remains in the cylinder. If we are using a 100-feet cylinder, it will gauge 120 atmospheres when full; 60 atmospheres will mean a residue of 50 feet of gas, and 30 will mean 25 feet left in the container. Intermediate amounts are easily calculated when once we know the capacity of the cylinder gauged. It is always well to keep a check upon the gas supply, for it may run away through the valve not being fully closed, or through an unsuspected leak, or a fault in the packing round the keyhole. Cases are not unknown where a lanternist, reasonably reckoning on a certain amount of gas, has found just previous to an intended performance an empty cylinder, and instances are still more frequent when the gas supply has run short before the proper conclusion of a lantern exhibition.

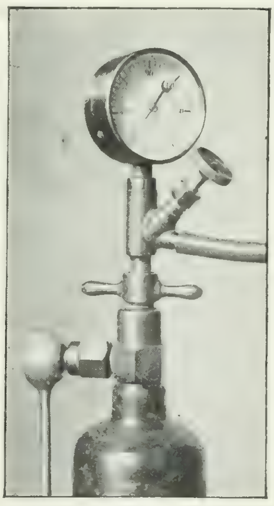


FIG. 7.—PRESSURE GAUGE ATTACHED TO CYLINDER.
When the cylinder is full the gauge indicates a pressure of 1,800 lb. per square inch, or 120 atmospheres.

Fig. 8 represents a cheap but serviceable Russian iron lantern, which can be used for mineral oil or for limelight. Such a lantern is admirable for home use or for class teaching in a schoolroom. The picture shows a useful form of slide carrier, working to and fro, the operator's hand

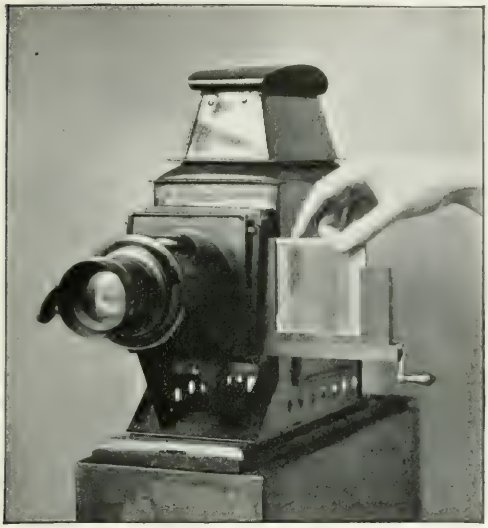


FIG. 8.—A USEFUL LANTERN: THE "SLIDE" BEING INSERTED.
The body of the lantern is of Russian iron.

being in the act of inserting a lantern slide, which will presently be pushed in front of the condensing lens.

The light of the lantern should proceed from one point so far as that is possible, and the nearer it conforms to this condition the better will be the definition of the picture on the lantern screen. To put it in another way, a lantern lens which gives a blurred picture with the big flame or flames of a mineral oil lamp behind it, will be much improved if the limelight jet be substituted for the oil wicks. It is for this reason that the incandescent gas mantle, which is so excellent for general illumination purposes, is quite unsuited to the lantern, although many persons have endeavoured to employ it for the purpose, and have been tempted to do so because of its brilliance. Of all the minor luminants employed for lantern purposes, the small, bright flame given by acetylene gas is by far the best. It is not nearly equal to a good limelight, but it is not to be despised if a disc, say, of not more than 6 feet in diameter is shown. With a good limelight an 18-feet sheet can be well covered. But the king of all lights for lantern purposes is the electric arc. The writer has covered a sheet measuring 30 feet across at several large halls in different parts of the country with the aid of this splendid light, and he would not hesitate to show a much larger picture if it were needed.

The electric arc light is produced between two carbon pencils, and a proper lamp or regulator is necessary to hold these pencils and to urge them towards one another as their points become gradually worn away. Such a regulator is shown at Fig. 9. It is the outcome of extensive practical experience, and has received much of that flattering approval which manifests itself in the form ot close imitation. It will be noticed that the carbons are not upright, but lie at an angle. The reason for this is that the upper, or positive, pencil is quickly hollowed out by the action of the current, and from the cavern thus formed the bulk of the light comes. By sloping the carbons this cavernous opening is presented towards the optical system of the lantern, and much more light is therefore available than if the pencils were truly vertical.

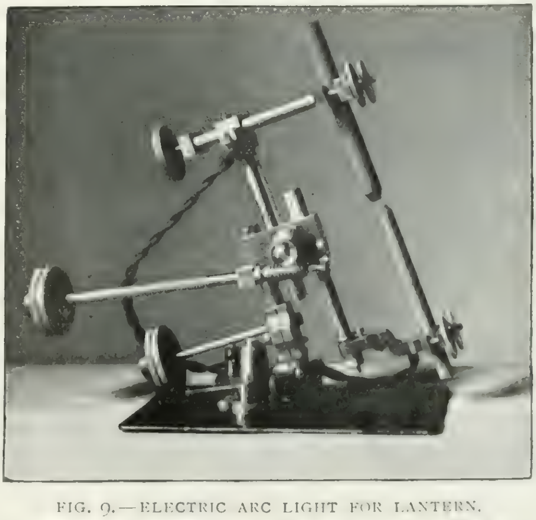


FIG. 9.—ELECTRIC ARC LIGHT FOR LANTERN.
Pictures of 30 feet diameter can be well illuminated with this brightest of lights.

For the same reason the upper carbon is not in line with the lower one, but is somewhat behind it, so that the cavern can be formed on its face rather than beneath it. As the positive carbon wastes away at double the rate of the other one, it is usual to make it double the thickness, so that the shortening of the two may be even. In this lamp the carbons are approximated by the action of the longest handle shown, the duty of the topmost one being to regulate the position of the positive carbon with respect to the negative, while the lowermost one raises or lowers the entire arrangement so as to centre the light vertically. The horizontal centering is brought about by a screw on the base of the instrument.

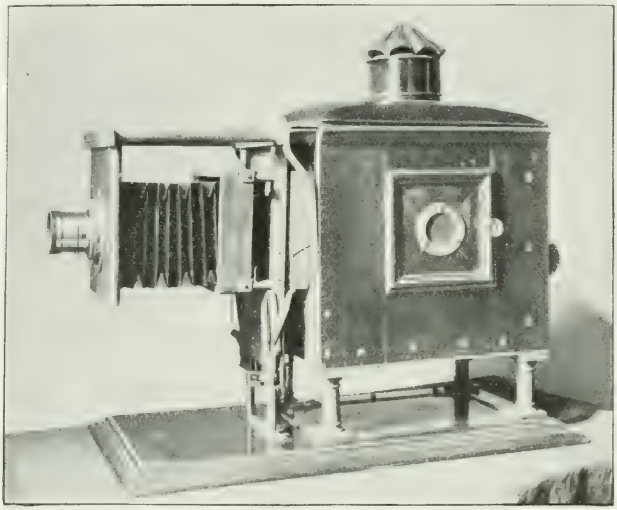


FIG. 10.—A HOME-MADE LANTERN.
The body is of wood, metal-lined. Plenty of air is admitted from below, for the contrivance is supported upon brass pillars.

The continuous current should, if possible, be used for lantern work. The alternating current gives a very inefficient light, and has other disadvantages into which it is needless to enter here; a limelight is much to be preferred. The efficiency of the electric light for projection purposes was proved at the great electrical exhibition held at the Crystal Palace, Sydenham, about ten years ago. The lantern was erected in the end gallery of the large theatre there, more than 100 feet distant from the screen upon which the pictures were projected.

It was difficult then to decide upon the form which the lantern should take, and the instrument used was quite an experimental one. Later on one was specially built, and, although this is not put forward for a moment as a perfect instrument, I can claim confidently that it is convenient in use, and gives very fine results. (*See* Fig. 10.) The objective lens is screwed into a front board, to which a leather camera bellows is attached, the whole sliding in and out of the lantern by means of telescopic tube supports above. The lantern proper is of wood, lined with metal, and plenty of air space is secured by leaving the bottom open, and supporting it upon corner pillars of brass. The lantern slides are inserted at the top in a special form of fixed carrier, which has a movable shutter. The effect upon the screen when a picture is changed is that of a dark curtain quickly covering the picture, immediately rising again to discover a fresh one. This lantern has been used to show pictures of 30 feet in diameter.

VENUS AND THE TRANSIT OF 1882.

WE do not know when the bright planet of our evening and morning skies was first distinguished by its motion from other stars. The Greeks knew it under two different names (Phosphorus and Hesperus), and in some cases mistook it for two distinct objects, one seen before sunrise and the other after sunset. The fact that these apparently twin attendants on the Sun are really one must have been known to the Babylonians, for a broken Assyrian tablet —of probably at least sixteen centuries before Christ—concerning the planet Venus, has the following succession of broken lines : "The planet Venus . . . it passed across . . . the sun . . . across the face of the sun." It is difficult to explain this last sentence, as the Rev. S. J. Johnson points out in the "Monthly Notices" of the Royal Astronomical Society for 1882, otherwise than by supposing that an actual transit is recorded, and where an actual transit of Venus across the Sun's face was either observed or computed it must have been perfectly recognised by the observers that the morning and evening stars were apparitions of the same body. But after the decay of Babylonian civilisation — in whose prime there is an ever-increasing accumulation of evidence to prove that planetary observation had attained a high order of excellence—we come to a long interval in the history of the planet, occupied only by a few observations of Greek and Arabian astronomers, to find it attracting its first special interest for us at the time of the invention of the telescope.

But there is some valuable, though negative, information to be gained from the naked-eye observations of Venus during this long interval. The claim is continually being put forward nowadays that on occasion the crescent, or gibbous, phase of Venus can be detected with the naked eye. But the Greek and Arabian astronomers who followed the motions of this brightest of all planets had surely eyesight no less keen, and an atmosphere clearer, than ours ; and yet there is no record of any observation of Venus as a disc out of the full, no suspicion that she was subject to changes like the Moon. On the contrary, it was objected to in the theory of Copernicus, which made Venus an interior planet (Fig. 1)—one, that is revolving between the Earth and the Sun—that in this case it should show phases like the Moon's, and, according to somewhat uncertain tradition, Copernicus replied that such was in fact the case, and that these changes would one day be distinguished. However this may be, it is certain that one of the earliest revelations of the telescope in the hands of Galileo was that Venus *did* pass, like the Moon, from a slender crescent when near the Sun to fuller roundness as it withdrew from it. When this most interesting fact was discovered by him, he was divided between the wish to withhold the news of it till he could make more complete observations and the fear that, if he kept silence, someone else might anticipate him in the announcement. In our days a scientific man, under such circumstances, would probably write the history of his discovery, and deposit it, under seal, in the custody of some learned society, so that he might establish his priority if it were afterwards questioned. Galileo solved his dilemma by another means then in use, which he employed with uncommon ingenuity. There is a familiar

game which consists in taking the letters which form some common word and giving them, jumbled into disorder, to an opponent, who is to arrange them, if he can, to re-spell the word which they compose. Galileo first briefly wrote his discovery in the words, "*Cynthiæ figuras æmulatur Mater Amorum*," or (freely rendered) "Venus imitates the phases of the Moon." He might have simply printed, in irregular order, the letters which compose the above sentence, with tolerable confidence that no one but himself could re-compose them into their true meaning; but he did more, and himself re-composed them into still another sentence, "*Hæc immatura a me jam frustra leguntur, o.y.*," or, "These things, unripe (for disclosure), are as yet deciphered in vain by me" — *i.e.* though he had made the discovery, he was not yet able to announce it. Anyone who will take the pains to devise a similar anagram will perhaps be of the opinion that the work is as difficult as the original observation it embodies, if not as meritorious. However this may be, the device served its purpose, and no one has ever disputed Galileo's claim to the discovery.

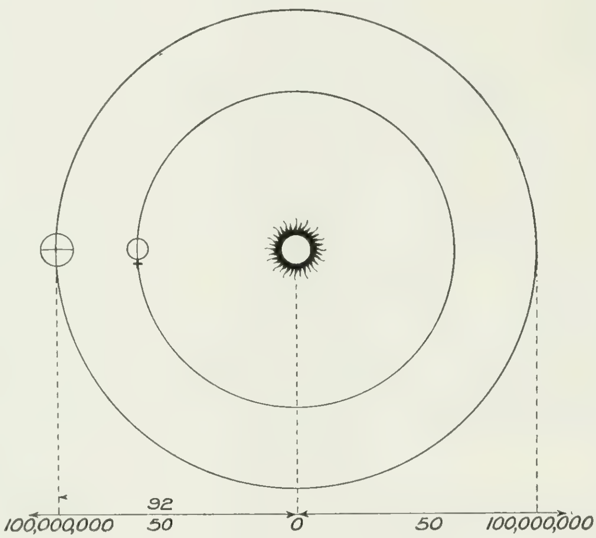


FIG. I.—ORBITS OF THE EARTH AND VENUS, SHOWING THE SCALE OF THE SOLAR SYSTEM.

Since Galileo's day we have learned the distance of Venus, her magnitude, mass, and density, and that she has an atmosphere—a dense one, and probably constituted to some degree like our own. But of Venus herself—her physical features; the distribution of her land and sea—if, indeed, she has land and sea; her changes of day and night—if, indeed, she has any such change; her seasons—if there be, indeed, spring and autumn, summer and winter, recurring in her latitudes—we know little more than did the first astronomers who studied her beautiful but expressionless face in the telescope. We know nothing with certainty about all these things. It is not the fault of our powerful modern instruments, for great aperture means great light-gathering power, and Venus is brilliant in herself, too brilliant for the unprotected eye to bear in even moderately large telescopes. It is not that she is too tiny an object, for when she is midway between her greatest elongation and inferior conjunction and well placed for seeing, she has an apparent diameter of 40″, so that with a magnifying power of only 45 she looks exactly like the moon when four days old to the naked eye. The fault does not lie with us or with our diligence in observation, but with Venus herself, and with her dense and brilliant atmosphere. All observers (except Mr. Percival Lowell, of Flagstaff, Arizona) agree as to the reality of an atmosphere round Venus. There is a rapid diminution of brightness where lies the terminator or dividing line between the light and dark hemispheres; there is an extension beyond a semicircle of the horns of her crescent, and, indeed, in 1898, Mr. H. N.

Russell, of the Halsted Observatory, observed the complete coalescence of the cusps when Venus was only 1° 45′ from the sun's centre; and in transits a "silver thread" has been seen surrounding the limb of Venus not yet entered on the sun's disc.

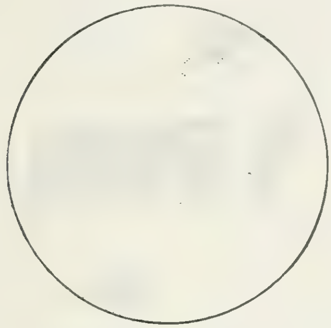


FIG. 2.—A FEW ILL-DEFINED SHADINGS UPON THE DISC OF VENUS.

Spectroscopic examination of Venus by Professor Vogel in the years 1871–73 showed her spectrum to be a very close repetition of the sun's, with but slight intensification of a few water and oxygen lines, and these, Miss Clerke points out, are so slight as to induce the belief that most of the light that we receive from Venus has only penetrated through her uppermost and attenuated atmosphere. In other words, we see sunlight reflected from the lower, denser strata of the atmosphere of Venus, and not from her actual surface; and, from a combination of the determinations of her brightness made by Professors Zöllner and Müller, Miss Clerke gives her *albedo* or reflective power as but little inferior to that of new-fallen snow.

Since clouds, or even a rather thick atmosphere, on our own globe effectually hinder us from making celestial observations, it is not to be wondered at that our telescopes are powerless against the mists and clouds of Venus, so that observers may watch her for months and years and see nothing, or see that which is but uncertain, faint, and illusory.

There has been a noble array of workers in this field—Domenico Cassini in the seventeenth century; Bianchini, J. J. Cassini, and Schröter in the eighteenth; and in the nineteenth De Vico, Schiaparelli, Vogel, Lohse, Holden, Perrotin, Tacchini, Mascari, Cerulli, Trouvelot, Niesten, Villiger, Brenner, Stanley Williams, MacEwen, Denning, Antoniadi, and Lowell, among many others. All these, except the last, agree as to the nature of the markings that are seen, though few of them show drawings that are very accordant with those of any other observer. These markings are a few ill-defined shadings, scarcely less bright than the rest of the brilliant disc (Fig. 2), and showing a strange tendency to lie symmetrically about the terminator. An irregular formation of the terminator (Fig. 3), which Schröter attributed to extraordinarily high mountains, may be simply due to cloud strata situated at very different heights, possibly accumulated above mountain peaks. Mr. Lowell, on the other hand, sees none of these things, but, instead, a manifold network of narrow, sharp, well-defined lines; but the evidence against his observations is so overwhelming that they may be dismissed as being due to some merely personal idiosyncrasy.

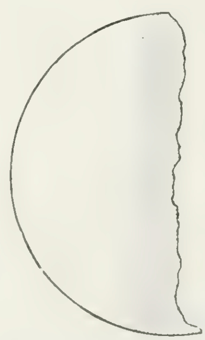


FIG. 3.—SOME SHADOWS SUGGEST THE PRESENCE OF HIGH MOUNTAINS.

It is upon the establishment of some permanent mark that lies almost our only chance of learning in what time our near celestial neighbour turns on her axis, and what is the inclination of her equator to the ecliptic; in other words, what is the length of the Cytherean day and night, and whether her seasons are invariable or changing as on this earth. Schröter

assumed the reality and permanence of the shadings he saw, and deduced a rotation period of 23 hours 21 min. and an inclination of the axis of rotation to the orbital plane of 53° 21′. Schiaperelli similarly assumed the actuality of the shadings seen by him, and deduced a rotation period of 225 days (namely, one equal in length to her revolution, so that she would turn an invariable face to the sun), and a coincidence of her equator with the orbital plane, so that her seasons would be also invariable. These are the heads and founders of the two great schools of thought on the subject, and in the absence of any decisive proof from Venus herself it is a matter of faith and personal predilection on the part of any astronomer as to which side he ranges himself on. The more scientific stand to take upon the question is the agnostic one expressed in the words of M. Camille Flammarion in *Knowledge*, November, 1897 :—

"We believe that nothing can be affirmed regarding the rotation of Venus, inasmuch as the absorption of its immense atmosphere certainly prevents any detail on its surface from being perceived. The most careful discussion of all the observations leads us to think that the grey spots now and again seen upon Venus are the effects of contrast due to solar illumination, and that the less definite shadings are of an atmospheric nature, incapable of furnishing us with any serious data as to the rotation of the planet. . . .

"We are sure of nothing. The globe of Venus may turn underneath its opaque envelope without any motion manifesting itself to our eyes, unless by some transitory and uncertain effects. No one has ever seen on the surface of Venus any clearly characteristic spot analogous to those shown on the discs of Mars and the moon. The maps of Venus made up to the present time are an illusion."

Besides watching and timing the passage of a planetary marking across the disc, there is another possible way of theoretically determining the speed of rotation of a body. This way is based on what is known as Doppler's principle, which is employed in measuring the motions of stars in the line of sight. When an observer and a source of light are approaching each other, the lines in the spectrum of the latter due to its light (whether intrinsic or reflected light) are shifted towards the blue end; and, when they are retreating from each other, these lines are shifted towards the red. Now, in the case of a planet rotating on its axis, if an observer be situated in the plane of the planet's equator, one edge of the disc will be approaching him whilst the diametrically opposite edge will be retreating from him at the same rate, and the lines of the spectra of the two limbs will be shifted in opposite directions, and the amount of shift will gauge the swiftness of the planet's rotation. This experiment was tried on Venus in 1900 by M. Bélopolsky, but with very dubious results. His results, doubtful as they are, tend to confirm Schröter's short period. On the other hand, about an equal amount of confirmation of Schiaparelli's rotation period may be found in the fact that Venus shows no appreciable flattening of her poles, which it might be expected that the swifter movement of a body when in a viscid state would tend to produce. Even this, however, is discountenanced by the fact that we do not know in what direction the poles of Venus lie, and much of the flattening might be masked by her great irradiation.

A curious phenomenon, of which no plausible explanation has been given as yet, is the occasional appearance of light on the dark part of the planet's surface, so that the whole disc is visible, just as in the case of "the old moon in the new moon's arms." This was seen by Riccioli in 1643. Similar appearances have been

seen by Schröter, Banks, Green, Noble, and on January 26th, 1902, at 4 h. 30 m. by Mr. Henry MacEwen, at Glasgow. In the January of 1883 Professor Zenger observed it on several successive mornings at Prague, and, like Riccioli, described a ring of brownish-red colour all round the planet, but more pronounced on the side of the illuminated crescent, the colour being not unlike that of the eclipsed moon. The dark part of Venus varied from reddish-yellow to reddish-grey—not bluish-grey, as Riccioli saw it; and Zenger affirms that Venus' dark side is visible not by fluorescence of her sea or by her auroral light, but simply by the same cause as that which makes the moon's dark side visible—viz., illumination by earth-shine. This is impossible to accept, since at our nearest approach to Venus we are one hundred times as distant from her as we are from the Moon, and hence the light which she receives from us is but one ten-thousandth part of that which is received by the Moon ($100 \times 100 = 10,000$), certainly far less than anything which we could possibly detect.

During the eighteenth century it was supposed that Venus had a satellite or attendant moon of its own, but it has not since been recognised, though its appearance and position were fully described by numerous skilled observers. The observations were, however, carefully discussed by M. Stroobant in 1887, and he succeeded in showing that in nearly every case the supposed satellite was really a small star—in one instance it was the planet Uranus—and he thus satisfactorily cleared up one of the enigmas of astronomical history.

We have now noticed the principal physical features of the planet, which, however brilliant an object to the naked eye, reveals on the whole less to the telescope than Mars or Jupiter or Saturn; and, were this all, when we have added that it is of about the dimensions of our own Earth, our account of it might be already concluded. But Venus has had a wholly different kind of interest for us, and one connected with what Sir George Airy called "the noblest problem of astronomy," the problem of the sun's distance from the earth.

Fig. 1, which might be called a map of part of the planetary system, should be referred to here. This could have been drawn about as accurately as it is here given even in Galileo's time, with one very important exception—that it then could have had no *scale*. Kepler had discovered a relation between the distances of the planets from the sun and the times in which they revolve round it. His rule (the squares of the times are as the cubes of the distances), which he discovered by immense labour, in guessing and trying all kinds of rules till one was found to work, might be thus expressed: If you want to know the distance of any planet from the Sun, as compared to the Earth's distance, take the time of that planet's revolution, expressed in parts of the Earth's time, square it, and find the cube root. Thus, the Earth's time of revolution being 1 year, and that of Venus a little over $\frac{6}{10}$ths of a year, or, more exactly, ·615, we find that ·615 times ·615 is ·378225, and the cube root of this is ·72 nearly. This, then, is the distance of Venus from the Sun, as compared with the Earth's distance taken as unity; it is, in other words, about 72 per cent. of ours; and in this way, thanks to Kepler, even in Galileo's days, by simply noting the time it took each planet to revolve about the Sun, a brief and simple computation would show its distance from the Sun as compared with ours, and so an accurate chart of the whole planetary system could be made. But what *is* our distance? Unfortunately, Kepler's laws tell us nothing about that. We may have a complete map or

chart of the solar system, then, without knowing upon what scale it is drawn. If, in other words, the distance of the Earth from the sun, in Fig. 1, is one inch, we do not know from anything yet explained here whether the inch stands for one million or for a hundred million miles, nor, consequently, do we know what any other distance is in figures, though we may be sure that all the *proportions* are perfect.

Now, it is plain that what we want is the actual distance in miles of any *one* of these planets from the Sun; for if we know the Earth's to be 90,000,000 miles, for instance,

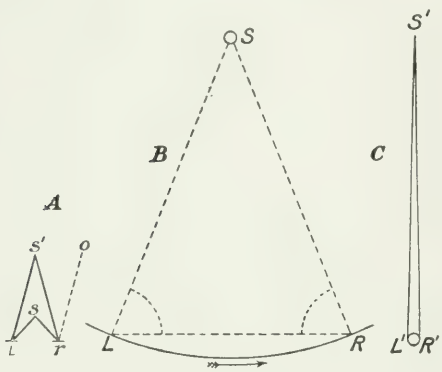


FIG. 4.—LARGE AND SMALL BASE-LINES.
L R, a large, and L′ R, a small, base-line. S. The Sun.

then that of Venus is 72 per cent. of this, which is 64,800,000, and so on for all the other planets.

Astronomers sought diligently, therefore, for a long time to find the Earth's distance from the Sun, but with very poor success.

The difficulty lies in the immensity of this distance, as compared to the Earth's diameter. Since immense distances are well known to be the particular subject of astronomical measures, it may be worth while to see why this one offers such peculiar difficulty.

The *principle* on which we proceed to find the distance of an inaccessible object is entirely independent of that distance, and is just the same whether the object is a tree on the other side of a river or the far-off Sun. The bee-hunter in the American forests who seeks the tree in which the wild swarms have deposited their honey proceeds to discover its distance by a simple means, with which he unconsciously works on exactly the same principle as the surveyor or astronomer.

The wild bee when laden flies in a straight line (a "bee-line") to its hoard, which is often miles away. The hunter, provided with a little honey, waits till a wandering bee has supplied itself, and then fixes the direction of its flight by "lining" it with some remote object. This tells him the *direction* only of the hive, but not how far off it is. Next he walks away, nearly at right angles to the line the insect took, for a quarter of a mile or so, and again proffers his honey. Some other of the numberless roamers from the same hive supplies himself at this second station and flies homeward. Again the hunter "lines" its flight, which is sure to be in a different direction to that of the first, precisely because both are tending to the same place, and the amount of change in this direction shows whether this place is near or far. The two lines must meet somewhere, and in one point, like the two sides of a capital **A** (disregarding the connecting line of the letter). If it is far off the Λ has long sides and a sharp angle; if near, short sides and a wide, open angle. (*See* Fig. 4, where, in the first (A) illustration, *l s′ r* is the sharper, and *l s r* the more obtuse, angle.) The hunter can roughly estimate the distance to the point, then, when he knows whether the angle between the sides is acute or obtuse; and this he learns without going there, from the difference of the two directions, which just equals it, as will be readily seen. The length between his two stations is called a "base-line" (it is the distance between the two legs of the Λ). The angle at the summit of the Λ is called by

astronomers the *parallax*. For a given base-line, then, a distant object has a small parallax, and *vice versâ*, so that it is easy to see that a very small parallax implies a very great distance, and it may be as readily seen that what the hunter does roughly a mathematician might do exactly, or that it is possible by exact calculations to tell *just* how far off an object is if we can learn its precise parallax.

The distance of an inaccessible object, then, is measured on quite the same principle by a surveyor, who employs instruments for the purpose, and calculates where the hunter roughly estimates. Thus, let S, in the second (B) illustration of Fig. 4, be a distant tree, and L the place where the surveyor first stands. He lays out a line of measured length, L R (the "base-line"), finds while standing at L the precise direction of S (*i.e.* the opening between L S and L R), and then repeats the process while standing at R and looking thence at S and back to L. The angle between L S and R S is thus found without going to S, where they meet, and this being known the lengths L S and R S are fixed. If now we take, in the same figure, S to mean the Sun, and L and R to be successive positions of the Earth in its annual orbit, though the principle remains quite unaltered, it cannot be applied in the same way, because if L be the station which the Earth occupies at any moment, there is nothing to distinguish R, the point in the void of space it will occupy later, nor when the Earth has moved on to R is there anything left to mark where it formerly passed, at L. The motion of the Earth round the Sun is, then, no help to us, and we have to give up this way, and try to see whether it is possible to apply the same principle within the limits of the Earth itself. The task is now immensely more difficult than if we could use two distant stations, for it was the different *directions* of the lines drawn to S from the stations L and R which enabled the hunter to find the hive, or the surveyor to measure the distance of the tree. The amount of this difference for a given distance of S depends, as we have explained, on the distance between the stations L R (the "base-line"); and if this base-line were to be reduced to a mere dot, evidently the two lines drawn to it from S would almost merge into one, and there would cease to be any sensible difference in their direction. The third (C) illustration of Fig. 4 represents the Earth as a base-line, with the Earth the size of a pin's head; but the actual proportion to the Sun's distance would make it far smaller—smaller than the least visible dot.

This difference of direction, as we have already said, is called by astronomers *parallax*, a word which is used by them so often and is so important that a further illustration of its meaning is not superfluous. We cannot measure the distance of the Sun without a base-line of some kind; we cannot get off the Earth to lay down a long one; and hence we must work, if we work at all, under the disadvantage of a base so small that it—even the longest we can get by going to two opposite sides of our globe—is a mere dot in comparison with the Sun's distance. If the space between a man's eyes stand for the distance between the two most widely possible separated stations on the Earth, then, on this same diminutive scale, the distance of the Sun would be over *half a mile*. The two lines drawn to the eyes from a point representing the Sun's centre would be almost parallel; either would have about the same direction as the other, and the difference of their directions (the *parallax*) would be almost nothing.

There is no way out of this difficulty. We must measure, if at all, under just the same conditions as a man would deal with who was called on to find the exact distance of a point half a mile off without moving from where he stood. The actual methods used by astronomers in

determining this minute solar *parallax* by means of Venus are highly refined, and the processes tedious, but the underlying principle is of the utmost simplicity, and any reader who cares to understand it may do so. Let anyone hold up a finger between his eyes and the window, and as near the face as he can distinctly see it (Fig. 5). Keeping the head and the finger motionless, let him close the left eye, and, using the right, notice the part of the window the finger appears to cover, D,

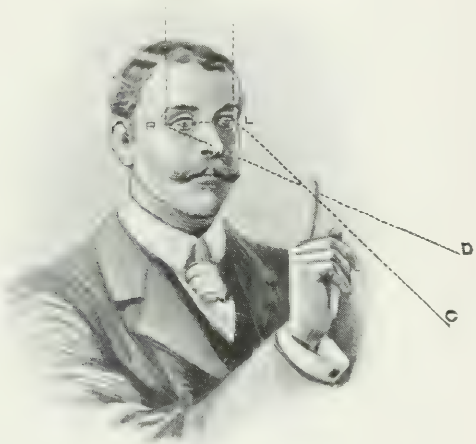


FIG. 5.—ILLUSTRATING THE MEANING OF "PARALLAX."

L and R, the left and right eyes, respectively, of the observer, represent the ends of the base-line; the finger is the object looked at; C, the point seen by the left eye; D, the point seen from the right.

and next repeat the observation with the left eye while the right is closed. The finger will now be seen to cover a quite different spot, C, though neither it, nor the face, nor the window has moved. This apparent angular displacement is due to the different direction in which the finger is seen from two different points of observation, *i.e.* the two eyes; it is, in other words, the *parallax* of the finger, and if this be now held at arm's length it will still be displaced, but obviously less than before, since the two lines drawn to it from the two stations of observation (the two eyes) are now more nearly parallel, and the *parallax* is smaller. This unfamiliar word, therefore, covers a familiar thing. The *parallax* of the finger is, in still other words, the angle under which our two eyes would be seen by the finger if that could be imagined to look at *us*. It is plain enough, as we repeat, that these things, *distance* and *parallax*, are so linked together that neither can change without a change in the other, and that a *small parallax* implies a *great distance*, as a small angle of the Λ implies long sides, though the object may be so far off that it does not apparently shift its place at all, in which case the point of the Λ is so distant that its two sides are almost parallel, and the only conclusion we can draw from the object is very remote indeed. Looking at some distant object, such as the corner of a building across the street, we shall see it then appear to move very little, whichever eye we use; that is its *parallax* can hardly be observed. We might, even in this case, get an idea of the amount of *parallax* by taking advantage of a very rare event in our streets—the passing of a body with extreme slowness and regular motion, such as when some great mass, like the obelisk in New York, or that on the Thames Embankment in London, is drawn along by a windlass with a steady but almost imperceptible movement; for clearly this slow-moving body would, if coming from left to right, cut off the sight of the opposite corner from the left eye before it eclipsed the view from the other, and the small *parallax* would thus be made sensible; but the application of such a method as this must evidently be very rare.

The conclusion to which astronomers came in the beginning of the eighteenth century about the Sun's parallax was that it was immeasurably small. Copernicus and Tycho Brahe, following still earlier computers, had estimated that the Sun was at least 5,000,000 miles off. Kepler called it at least 13,000,000 miles, and every

measurement, as observation grew more accurate, only went to show that the "parallax" was—at any rate to the means then in use—immeasurably small, and consequently the Sun's distance immeasurably great. It was already known with exactness, as we have seen, what the proportionate distances of the planets were from the Sun; but the absolute distance of the Sun itself from any one of them was thus lacking. A determination of the *solar parallax*, then—or, in other words, of the distance of the Sun from the Earth, and the consequent knowledge of the scale on which the Universe was built by its Architect—remained wanting.

Under these circumstances, in the year 1716 the celebrated Halley pointed out a method of solving the problem, which depended upon the fact that at certain very rare intervals the planet Venus passes directly between us and the Sun. We shall not attempt here to describe at length the method of Halley, but only to give a clear general idea of the way in which Venus will enable us to solve the difficulty as to the Sun's distance.

Halley proposed, in substance, that two observers should be stationed at opposite sides of the Earth when Venus passed over the Sun's disc (which it does so slowly as to occupy several hours, during which time it is distinctly visible as a black spot). Looking towards the Sun from any point in England or the United States, the left hand is towards the east. Let the observer at the left or eastern end of the Earth's diameter then represent the left eye in our previous illustration (Fig. 5), and if the planet Venus be moving slowly across the Sun from left to right, as it does at certain rare intervals, it is plain that the left-hand observer will see it touch the Sun's edge before the other one sees it at all (for it is not distinctly visible until it is actually entering on the Sun). If the two observers have compared their chronometers, and know, consequently, when they afterwards meet, how may minutes and seconds one saw it before the other, this will enable us to calculate how long the planet was in crossing from the line of sight of the left observer to that of the right. But as we know just what part of a degree Venus moves in this time, we know just how small an angle the distance between the two observers makes as seen from the Sun, and this is the solar parallax, which shows us how far the Sun is away.

Thus, if Venus cross the Sun's centre (to suppose the simplest case), since she is known by common observation to revolve through her entire orbit of 360° in 225 days, in one minute she would move through 4″—that is, four seconds of arc. In the same way the Earth is observed to move through 360° in its year, which gives a motion of 2·46″ in one minute. Then the difference, or 1·54″, is the amount that Venus gains on the Earth each minute, and if the observer at the left-hand extremity of the diameter of the Earth saw it enter the Sun eleven and a half minutes before the other, $11\frac{1}{2}$ times 1·54″, or 17·70″, is the angle which the Earth's diameter fills to an eye at the Sun. It is usual to consider the Earth's radius instead of the diameter, and accordingly half of this, or 8·85″ (corresponding to a value of the semi-major axis of the Earth's orbit of 92,000,000 miles), would be the solar parallax. This value, 8·85″, was adopted in the "Nautical Almanac" about the year 1880, and remained until the issue of 1901, when the smaller value, 8·80″, was substituted, corresponding to a mean distance of 92,890,000 miles, as the most probable in the present state of the problem.

It is desirable to have many observers, stationed at different points, which need not be, in practice, at the extremities of the Earth's diameter. Halley proposed,

in fact, to have a great many such pairs of observers, stationed at different points on the Earth, lest, he says, "any single observer should be deprived by the intervention of clouds of a sight which I know not whether any man living in this or the next age will ever see again; on which depends the certain and adequate solution of a problem the most noble, and at any other time not to be attained to."

To see why this phenomenon is so rare, we must observe that though Venus revolves in a path interior to ours, she does not come exactly between us and the Sun every year or two (as might be supposed), because her orbit is inclined to our own. Thus, in Fig. 6, let the shaded curve represent the Earth's path about the Sun, and the unshaded one that of Venus. The planes of these two curves intersect in a line which goes through the points which the Earth passes each June and December. Only in these months can Venus by any possibility be seen on the Sun; only then on a certain day, and not on that day unless Venus happens to be there, for she may evidently happen to be anywhere else in her orbit (for instance, at the points marked ♀ ♀), and unless all these events concur she will not be seen "in transit." As thirteen of her revolutions take place (nearly) to eight of ours, if we *do* see her on the Sun, we shall very probably see her there eight years later. Accordingly the transits usually come in pairs eight years apart, but there is commonly an interval of more than a century between. The first transit ever known to have been observed, if we except the Assyrian record mentioned previously, was that on December 4th, 1639, which is supposed to have been seen only by two young Englishmen, Horrocks and Crabtree. Horrocks, who was a clergyman, had himself computed the circumstances of the transit, and successfully observed the later portion of it, a little before sunset. The transits which Halley foresaw occurred after his death, as he had predicted, in 1761 (June 6th) and in 1769 (June 3rd). Observers were sent all over the world by the principal Governments, and amongst the rest

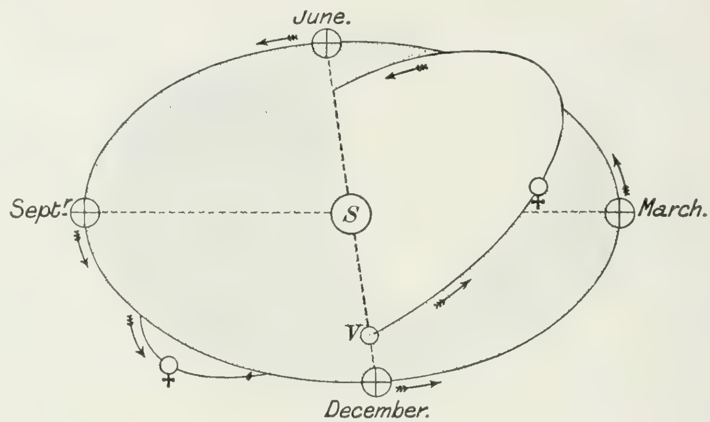


FIG. 6.—INCLINATION OF THE ORBIT OF VENUS.
The shaded curve shows the earth's path round the Sun. The unshaded curve the path of Venus.

the celebrated voyage of Captain Cook to Otaheite was undertaken for the transit of 1769. Captain Cook records in his journal that "we very distinctly saw an Atmosphere or Dusky shade round the body of the planet, which very much disturbed the times of the Contact, particularly the two internal ones." The results of these two transits were not fully discussed until well on in the nineteenth century, when Encke published his deduction of 8·58″, corresponding to a mean distance of the Sun of $95\frac{3}{4}$ millions of miles. This was accepted for some thirty years, when the growing discordances between the observed and computed places of the Moon and Mars and Venus stirred up astronomers to a fresh discussion of the

eighteenth century transit observations, and Powalky in 1864, Stone in 1868, and Newcomb in 1890 from the same data derived very much smaller values for the Sun's distance.

In 1874 another transit occurred, and extensive preparations were made by Great Britain and other European Governments, as well as by the United States. Photography was used very extensively, by taking pictures of the Sun's face with the planet upon it, but when it came to the measurement of the tiny disc from the all too undefined solar limb the discordances were found to be far greater than even in the case of visual measures; and these were difficult and uncertain enough, especially in the case of the internal contacts, in the timing of which, Colonel Tupman complains, observers side by side, with equal optical instruments, yet may differ by as much as twenty or thirty seconds, whilst using practically identical language to describe what they saw. From the British expeditions alone, and giving weights to the various observations as their judgments dictated, Sir George Airy, Dr. Stone, and Colonel Tupman derived the very various parallaxes of 8·75″, 8·88″, and 8·81″ respectively. The "Atmosphere or Dusky shade" of which Captain Cook complained in 1769 was again the serious factor tending to inaccuracy in 1876.

FIG. 7.—APPARENT DISPLACEMENT OF VENUS.
N and S are two observers, one at the north, the other at the south pole of the Earth. V. Venus. S N. Displacement of Venus upon the Sun's disc.

In 1882 another method, somewhat different from Halley's, was used in addition to it. In Fig. 7 we observe that of two persons, one at the north pole of the Earth, the other at the south, the northern one will see Venus lower down on the Sun's disc than the other. If Venus then is crossing below the Sun's centre, it would be seen from a station at the north pole to describe a shorter chord in its transit

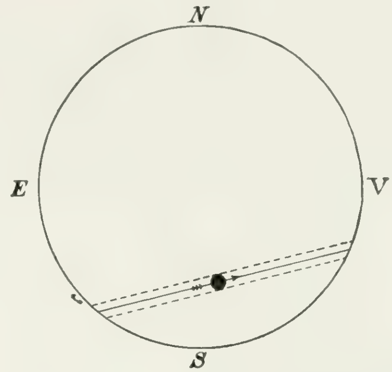


FIG. 8.—PATH OF VENUS ACROSS THE SUN: THE TRANSIT OF DECEMBER 6TH, 1882.

over the Sun than when seen from the southern; and the apparent displacement on the solar disc, bearing a known proportion to the known distance between our poles (the proportion is that of the distance of Venus from the Earth to her distance from the Sun, and these *proportions*, it will be remembered, are known already), we thus again have a measure of the solar distance. This is still further shown in Fig. 8, where the approximate apparent size of the planet on the Sun is given by the round black spot, the direction of its motion by the arrow, and the paths in which it will seem to cross to a northern and a southern observer are roughly indicated by the dotted lines. Of course, there is no need to attempt to reach the Earth's actual poles, though it is well to have stations as far apart as is practicable.

All the phenomena of the planet's entrance on the Sun's disc could be witnessed by the residents of the British Islands and of the Eastern United States, as the two following illustrations will show. Fig. 9 shows the appearance of the Earth as

seen from the Sun on December 6th, 1882, at the time when the planet is first entering on the disc. It will be noticed that the British Islands are just about to pass out of view as the globe turns from left to right, as shown by the arrow; in other words, the inhabitants of Great Britain could see the planet enter just before their sunset, and would then lose sight of Sun and planet together. Those living in Canada, the Eastern United States, and South America would not only see the beginning

FIG. 9.—THE EARTH AS IT WOULD APPEAR IF VIEWED FROM THE SUN ON DECEMBER 6TH, 1882: AT THE BEGINNING OF THE TRANSIT. *(After Proctor.)*

(Fig. 9) some time after their sunrise, but could witness the whole phenomenon to its close (Fig. 10). At the latter time the eastern and western coasts of America were both still in view from the Sun, and the Sun, with Venus upon it, was equally, of course, in view from such cities as New York, Montreal, and San Francisco. The figures upon the globe in each illustration show how much in time the ingress of the planet upon the Sun, or its egress from the Sun, were accelerated or retarded to observers at different points by the cause which we have explained in speaking of Halley's method.

But the results obtained in 1882 were scarcely more satisfactory or more certain than those obtained from the transits of the preceding century, when these had been discussed with judgment and discretion. Dr. Stone, who directed the British expeditions and discussed their results, obtained values as widely differing as 8·88″ and 8·82″, and these were all considerably larger than the values given by other independent and more certain methods of finding the sun's parallax. Thus, as early as 1874, M. Leverrier pointed out in *Comptes Rendus* that to reconcile the observed and computed movements of Mercury and Mars the one should have his perihelion motion quickened by thirty-one seconds in a century, and the other by about one-eighth; and, moreover, that the observations of the Sun, made since the epoch of Bradley at Greenwich, at Paris, and at Königsberg, to the number of 9,000, all seemed to be affected by some systematic error, and that all these irregularities might be accounted for by assuming that the then adopted parallax of the Sun (8·57″) should be increased by about 0·21″. The velocity of light had originally been deduced by taking the time of its passage across the assumed radius of the Earth's orbit; but now, reversing the process, an independent method of determining the velocity of light having been devised by Fizeau and Foucault, and much improved by Michelson in 1879, and by Newcomb in 1880–82, the mean radius of the Earth's orbit has been computed as about 92,900,000 miles, corresponding to a parallax of 8·80″ very nearly.

It will be thus seen that from every point of view our beautiful neighbour is a most unsatisfactory subject of observation. No matter how we question her, her evidence is ambiguous, uncertain, obscure; and she is so like ourselves—almost our twin sister in all that form the essentials of a planet—that there is much that we would like to learn from her, if

only as by a "giftie" from some power "to see oorsels as ithers see us," for assuredly as we see Venus, so Mars sees us. And perhaps in this new century now opening out before us we may, by new methods, new instruments of research, yet unguessed at, wrest from her those secrets that she now holds so closely. But when the twenty-first century has dawned, and again a transit of Venus is imminent, we may believe that it will be other information than our distance from the Sun that the astronomers of that day will ask from her.

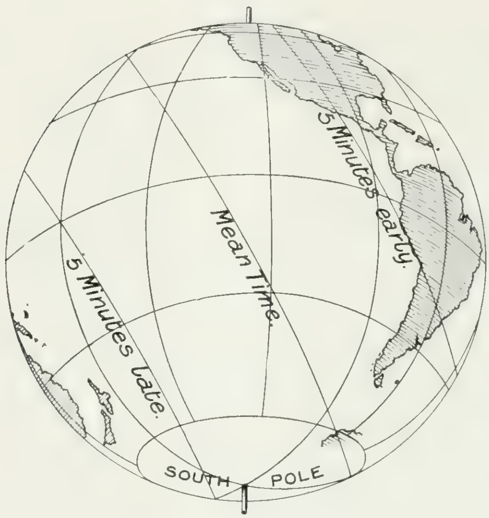


FIG. 10.—THE EARTH AS SEEN FROM THE SUN ON THE SAME DATE: THE TRANSIT COMPLETED.
(After Proctor.)

BUTTER.

By C. W. WALKER-TISDALE.

Lecturer in Dairy Farming and Dairy Bacteriology at University College, Reading.

FROM some recently compiled statistics we find that in the British Isles the consumption of this most important article of diet amounts annually to 236,937½ tons, equal to 13¼ lb. per head of the population, or approximately ¼ lb. weekly for each person. Now, of this large quantity of butter required to feed the populace, only a little more than one-third is produced at home. The manufacture of butter is, therefore, an industry of considerable importance.

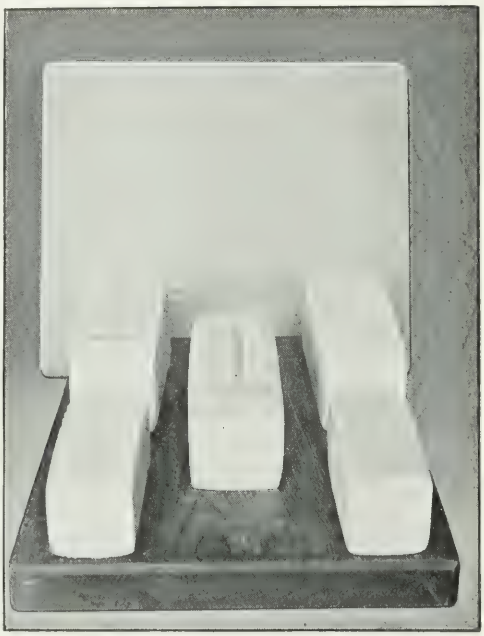


FIG. I.—THE FINISHED ARTICLE.

A glance at the table given in the article on "Milk"* will show the reader that one of the five constituents of which the latter commodity is built up is butter-fat. Now, this only constitutes a small proportion of the milk, generally somewhere between 3 and 4 per cent., but it is this constituent only which is of use to us for butter making. The quantity of butter yielded will depend upon the richness of the milk. For instance, Jersey and Guernsey breeds of cattle give an exceptionally rich milk, which is noted for its butter-producing powers, whereas the milk from Dutch cows is generally very poor in fat, so that it takes a large amount of such milk to make a pound of butter.

The first operation in the making of butter really consists of what we may call a concentrating process, which, in other words, is the separation of the cream, which contains most of the butter-fat, from the milk. Now, it must not be assumed that it is absolutely necessary to separate the cream from the milk. "Whole" milk may be churned direct, and this is a system of butter-making still largely practised in the north-west counties of England and parts of Wales, Ireland, and Scotland. When the "whole" milk is churned it is customary to sour it preparatory to churning, which gives a more complete conversion of fat into butter. As the churning of milk is a process confined to certain districts, and one which will soon be replaced entirely by the more modern method of churning cream, we need not give it very serious consideration. It has many disadvantages as well as advantages, and after the two are carefully compared the former undoubtedly outweigh the latter.

* CASSELL'S POPULAR SCIENCE, Vol. I., p. 124.

The separation of cream from milk is effected in many ways, but two are chiefly adopted—namely, the old-fashioned system of "skimming," and the more modern one of separating by means of centrifugal force.

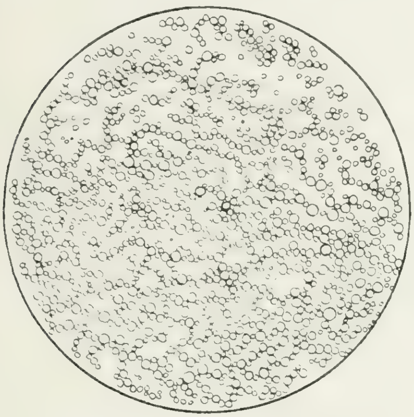


FIG. 2.—CREAM UNDER THE MICROSCOPE.
The globules are numerous but distinct.

Cream is really a concentrated, fatty milk. Unfortunately, it is never possible to get all the cream from the milk by the first of these methods, and much is lost in the skim milk. The loss, indeed, is so considerable that about ¾ lb. of butter is lost in every gallon of skim milk.

The quality of cream can easily be regulated where a separator is used, as the cream screw may be so adjusted as to take off from the milk in any volume required, and the greater the volume of cream the poorer will it be in fat. For butter making a comparatively thin cream is best, whereas for cream selling or cream-cheese making a thicker cream is necessary.

The following figures give the composition of :—

	Thin Cream. (Suitable for Churning Purposes.)	Separated Milk. (Average.)
Water	65·38	90·39
Fat	26·20	·10
Casein & albumen	3·25	3·90
Milk sugar	4·52	4·85
Ash	·65	·76
	100·00	100·00

The fat of cream may vary from 15 to 70 per cent.

If we examine a drop of cream under the microscope (Figs. 2 and 3), we see fat globules present in tremendous numbers. The large globules stand out prominently, and are so packed together that there is no mistaking cream for milk, which, indeed, seems to contain comparatively few. Now comes the process of preparing it for churning. It is a matter of custom to "ripen" or allow cream to sour before churning it, and the majority of butter is made from "ripened" cream. A considerable demand, however, has recently sprung up for sweet cream butter, or butter made by churning the fresh cream straight from the separator, before it has developed acidity. The sweet cream gives a cream-flavoured article with very few of the characteristic qualities of good butter; but as the price received for it is usually several pence per pound more than that obtained for ordinary butter, it pays to make it where customers give preference to it. Cream ripening is brought about by bacterial fermentation, which must be carefully controlled to ensure butter of good flavour. This fermenta-

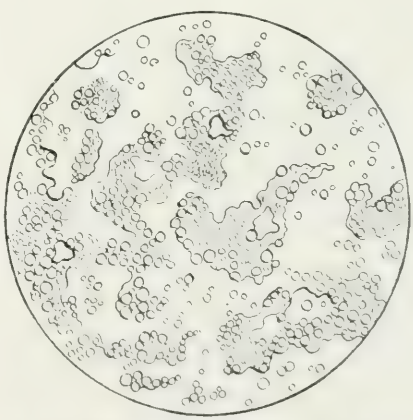


FIG. 3.—THE CREAM COMMENCING TO CHANGE TO BUTTER.
The globules coalesce and become viscid.

tion is of two kinds—(1) natural and (2) artificial, or perhaps a better term to use than (2) is "by use of starters."

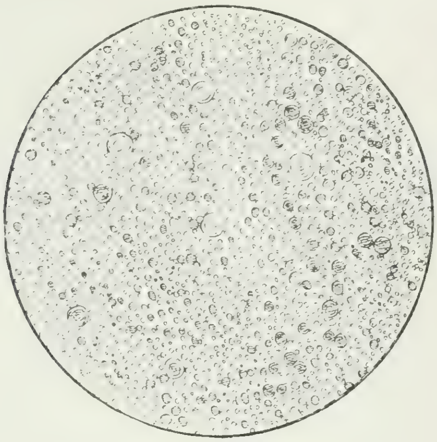


FIG. 4.—BUTTER UNDER THE MICROSCOPE.
Note the large, irregular globules of water and groundwork of fat.

Now, if we trace milk back to its source, we find that whilst in the udder it contains only a small number of bacteria, but as soon as drawn it becomes subject to aerial contamination, and absorbs bacteria from the surroundings. These grow in the milk very rapidly, as it is a perfect food and an excellent medium for them.* A short time after milking, several thousand bacteria in each cubic centimetre (about fifteen drops) may often be found. The process of separation removes a very considerable number from the milk, but the cream and separated milk still remain highly charged with various kinds of the minute organisms, and the cream, when set aside and kept at a suitable temperature, acidifies or ripens as the result of the growth of these and other bacteria absorbed from the air. This is known as natural ripening, and resembles the souring of milk, both changes being the result of lactic acid bacteria turning the milk sugar contained in both milk and cream into lactic acid.

* *See* "Milk," CASSELL'S POPULAR SCIENCE, Vol. I., p. 124.

Ripening cream by the use of starters is the more scientific method, as it really consists of inoculating the cream with cultures of suitable bacteria. By the quantity of "starter" used, and the temperature at which the cream is kept, the fermentation can be controlled to a nicety, and the cream ripened to within an hour or two hours of the time at which it is required for churning. The starter used may consist of some pure new milk, allowed to sour in a wholesome atmosphere, a given proportion of which is added to the cream to ripen it. Sometimes buttermilk is used as a souring medium, but for certain results pure cultures of lactic acid bacteria, as sold commercially or as prepared in the laboratory, are more dependable.

When the butter maker buys a five-shilling bottle of "pure culture," as it is labelled, he is buying lactic acid bacteria

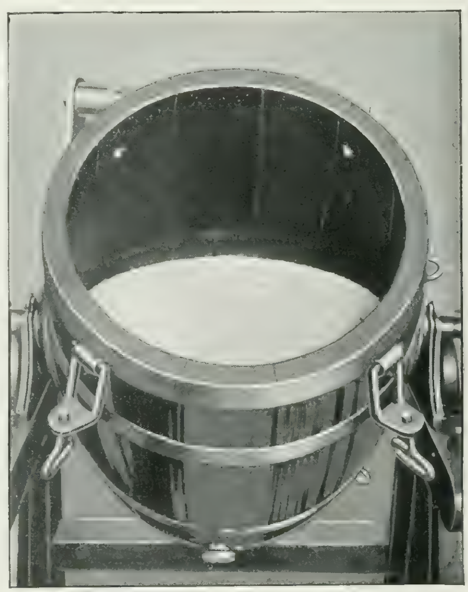


FIG. 5.—GRAINS OF BUTTER IN A CHURN.
Churning is now nearly finished.

with which to ripen cream or to use in milk for cheese making. He does not put the white powder from the bottle straight away into the cream, but first of all

FIG. 6.—BUTTER GRANULES.

The final stage of churning. The butter as ready for "working."

places it in a pail of pasteurised milk, which is allowed to sour. Some of the soured milk is then used. To ripen cream in about twenty-four hours "starter" is added at the rate of 5 to 8 per cent. in summer and 8 to 10 per cent. in winter, the temperature at which the cream is kept being 60° to 65° Fahr. Naturally ripened cream takes longer to ripen, as a rule, than that in which starter is used, the time taken varying inversely with the temperature of the surroundings—the higher the temperature the shorter the ripening period. Where large quantities of cream are dealt with it is usually ripened in large, jacketed vats, holding about 200 gallons (Fig. 8). The jacket is used to hold water, the temperature of which regulates the temperature of the cream during the process.

Whether the ripening is natural or artificial, the properly ripened cream should contain an acidity equivalent to 0·5 to 0·6 per cent. of lactic acid, and up-to-date butter makers, who manufacture on a large scale, commonly test the cream by means of an acidimeter. It is in this way that they know when it is ripe, so that they have a certain guide as to the correct stage at which to churn. In the same way that the brewer needs to aërate the wort so that the yeast cells may grow actively and produce a quick fermentation of sugar into alcohol, so the dairyman aërates the cream to supply the oxygen necessary for the growth of the lactic acid bacteria. There is, however, a difference in the degree of aëration required in the two cases. If the brewer aërates the wort too much, the yeast cells will not produce alcohol, but will turn the sugar into carbonic acid gas and water; in the process of cream ripening the cream cannot be aërated too much, as the more perfect the aëration the better the souring. Cream should thus be frequently stirred when set to ripen.

As soon as the cream has gained a sufficient acidity it will have a thickened consistency and glistening appearance, and is ready for churning.

Churning is a very simple process, and

FIG. 7.—APPARATUS FOR "WORKING" AND MAKING UP BUTTER.

consists of knocking together the particles of fat in the cream so as to make them coalesce and form butter (Figs. 3 and 4). The simplest kind of motion will perform churning; if either milk or cream is shaken up in a bottle, it will yield up its fat in the form of lumps of butter. Now there are many kinds of churns (*see* Figs, 5 and 9) used: some which revolve completely, others in which the churn itself is stationary, but contains movable dashers which revolve and so agitate the contents. Our Canadian cousins are fond of the cradle churn, which, by means of a rocking or oscillating motion, does the work extremely well.

Churns are made to churn from small to very large quantities of cream. Some are only of sufficient size to produce 3 lb. or 4 lb. of butter at a churning, whereas large factory churns are made to take 150 to 200 gallons of cream at a time, so that 500 lb. to 800 lb. of butter, according to the quality of the cream churned, are forthcoming at each operation (Fig. 9). The greater the concussion of the particles to which the cream is subjected the more complete is the conversion of fat into butter; hence it is never advisable to fill a churn more than half full of cream. Preparatory to churning, a temperature must be selected at which to work, otherwise the time may be too long or too short, and the quality of the butter suffer in consequence. Generally, the temperature at which churning is done may be from 50° to 56° Fahr. in summer, and 56° to 62° Fahr. in winter. The movements of the churn are at first slow, so as to allow of the escape of gases. The gases, which it is necessary to let off from the cream at this stage by pressing the ventilator of the churn, are generated in it as the result of fermentation or ripening, and are represented chiefly by carbon dioxide (CO_2), a by-product of bacterial growth in the cream. If this gas were not

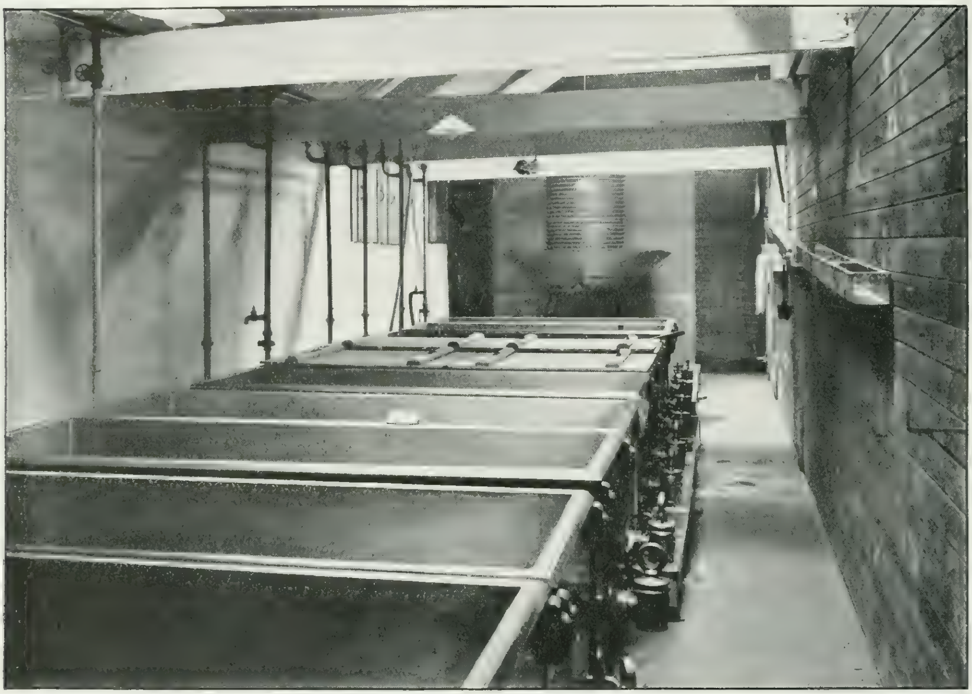


FIG. 8.—CREAM RIPENING VATS.

allowed to escape, it would prevent the conversion of cream into butter. After the carbonic acid gas has been expelled, the speed of the churn is gradually increased until about 50 to 60 revolutions per minute are attained, which speed is continued until the butter "comes." After the movements have been going on for some time, separation of the butter from the cream takes place; this stage may be told by noting the peculiar fall of the liquid in the churn, or by looking at the glass window, when the cream, instead of having a smooth appearance and evenly covering the glass, appears broken, and the window is partly cleared. At this stage the modern plan is to add a small quantity of cold water, known as "breaking" water, which keeps the "grain," or small particles of butter, from matting together and forming lumps, which they would otherwise do very readily unless the cream happened to be very thin and watery. The cold water also assists in hardening the butter grains.

A little more churning after this will bring the butter into beautifully rounded granules, which should be about the size of wheat grains (Fig. 6). The buttermilk is now drawn off, and the granules are washed two or three times with plenty of water to free them from all milkiness. If this milkiness is not got rid of, the butter does not keep well. The length of time taken in churning is generally about half an hour. The butter granules are now scooped out on to the "worker," which consists of a table on which is fitted a grooved roller (Fig. 7). This roller, when passed over the butter several times, removes most of the superfluous moisture. In working butter the great object is to preserve the granular texture by not squeezing it too much, but at the same time enough to remove the water.

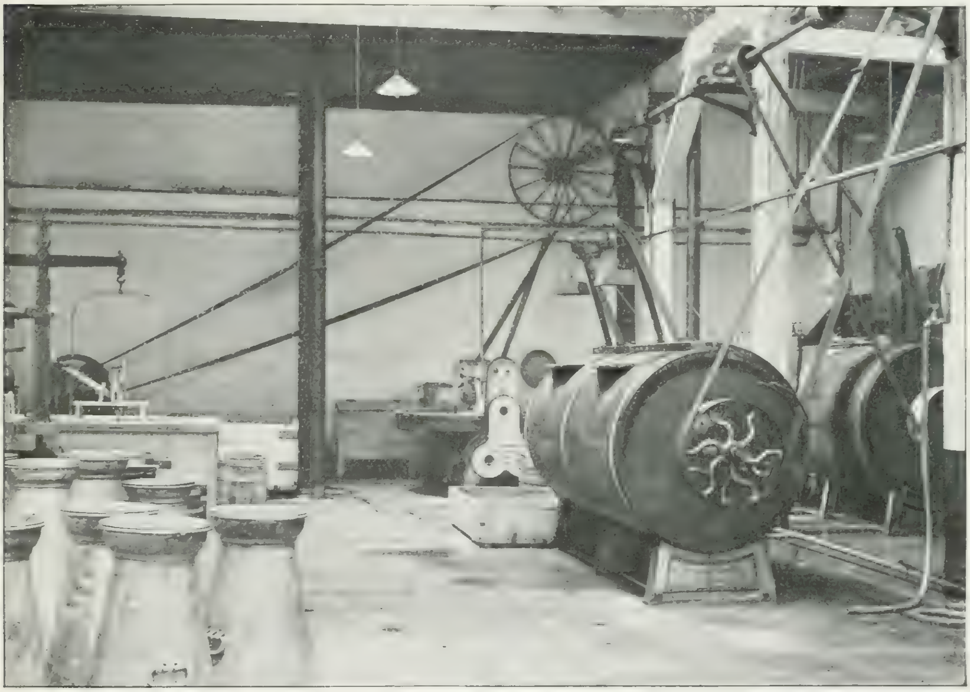


FIG. 9.—CHURNING BY MACHINERY.

Butter is salted in two ways. Either dry

FIG. 10.—REFRIGERATOR FOR MILK AND CREAM.

After "separation" the cream must be cooled before "ripening," otherwise butter of inferior texture results.

salt is added to it on the worker at the rate of $\frac{1}{4}$ oz. to $\frac{3}{4}$ oz. to the pound, according to degree of saltness required, and this is worked into it with the roller; or the granular butter may be soaked in a solution of salt (brine) whilst still in the churn and after the washing has been completed.

Having salted and worked the butter, it is only necessary to make it up ready for sale, and the manufacture is completed. From beginning to end the human hand should not touch it; and the age in which butter was freed from its water by being squeezed through the dairymaid's hands has happily passed.

A useful method of comparing the quality of two samples is to take two test tubes and fill them each with one kind. Melt the contents, and allow separation of the constituents to take place. On the top will be a layer of fat; beneath this a shallow white flocculent layer, which is casein; and at the bottom will be water. On comparing the two tubes it will readily be seen which sample is the better—viz., that which has the more fat and the smaller quantity of water, while the less casein there is the better the keeping properties. Salt is added to flavour and preserve.

Few people have any idea what quantity of milk a pound of butter represents. We shall find that on an average it takes $2\frac{1}{2}$ gallons of milk to produce 1 lb. A Jersey cow will give 1 lb. of butter from less than 2 gallons of milk, but in many instances it takes 3 gallons of milk to yield 1 lb. It takes about 1 quart of cream to make 1 lb. of butter; thus, if we split up 100 lb. of milk, it yields, say—

100 lb. (10 gals.) milk.

10 lb. cream. 90 lb. separated milk.

4 lb. butter. 6 lb. buttermilk.

Or 4 lb. of butter from 100 lb. of milk, which equals 1 lb. of butter from 25 lb. of milk (about $2\frac{1}{2}$ gallons).

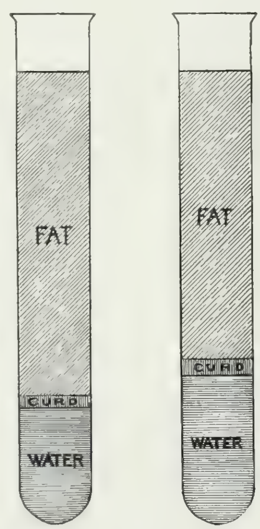


FIG. 11.—HOW TO BUY THE BEST BUTTER: A SIMPLE BUT SCIENTIFIC TEST FOR THE HOUSEWIFE.

The better the butter the greater the proportion of fat to water.

A good sample of butter (*see* Fig. 12) would have the following composition:—

Fat	85·0
Water... ...	11·9
Ash	2·0 including salt
Casein... . .	·6
Milk sugar ...	·5
	100.0

Butter-fat is the most complex and valuable of all fats, being almost wholly digestible, and in form a most suitable food for ready assimilation by the digestive organs. The percentage of water in butter varies inversely with the fat; the greater the percentage of water the less the fat, and *vice versâ*. The water contents must by law not exceed 16 per cent., otherwise the produce will be regarded as adulterated. Formerly butter might contain 20 per cent. of water, and yet be regarded as genuine. The water left is chiefly regulated by the amount of working it receives—the more the butter is worked the less the percentage of water left in it.

The casein causes decomposition, as it supplies the nitrogenous food necessary for the growth of bacteria; the more casein there is present the poorer will be the keeping qualities of the butter. Unless a little casein were present, however, butter would be flavourless and hardly distinguishable from other fats, for it is the small quantities of decomposition products which give the flavour—in fact, butter is not full flavoured till about two days subsequent to making.

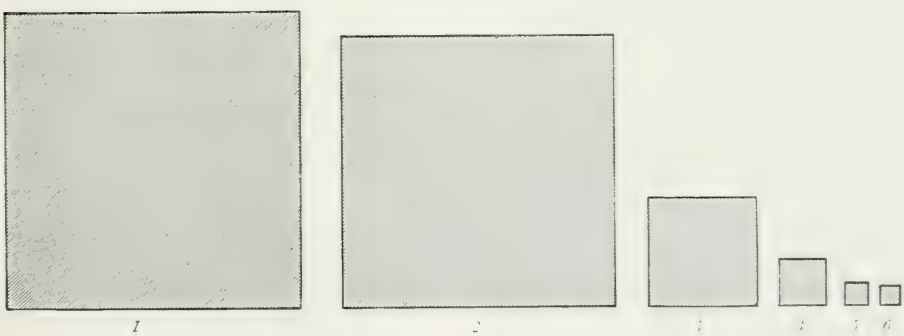


FIG 12.—A PAT OF BUTTER ANALYSED.

1. *Butter, 100 parts.*
2. *Fat, 85 parts.*
3. *Water, 11·9 parts.*
4. *Ash, including salt, 2 parts.*
5. *Casein, ·6 parts.*
6. *Milk sugar, ·5 parts.*

A VISIT TO A QUARRY.

OUR knowledge concerning the various rocks which compose the crust of the earth has been derived from a careful study of the different beds exposed in the many sections, both natural and artificial, that are more or less abundant in all countries. The cliffs that fringe the sea-shore, or overhang the banks of some rivers, and the inland cliffs or "escarpments" that form such prominent features in many of our landscapes, are examples of natural sections; whilst, among the artificial, we may enumerate quarries, railway cuttings, and deep well borings. All the beds shown in such a section as that figured in Fig. 1 are not found at one place. Some are sure to be absent; but all bear the same relative position to the others, no matter how few or how many are found.

In our own country a greater number of different beds, or sets of beds, occur than are probably to be met with in any other tract of similar extent, and a fair knowledge of their nature and fossil contents may be derived from the various rocks exposed in the faces of cliffs on our coasts; but the closest inspection of these sections would not enable one to trace out the direction and extent of the beds inland, and this can be correctly ascertained only by consulting numerous quarry and other artificial sections, aided by a careful study of the physical features of the country. Then, again, beds of the same age may, in different localities, consist of entirely different materials, such as limestone in one place, clay in another, and perhaps sandstone in a third. An observer going from one to the other would be most likely to set them down as altogether distinct deposits; whereas an examination of the intermediate rocks exposed artificially in quarries, and their fossil contents, would enable him to trace the connection which really exists between them, and to demonstrate the identity of their age.

Besides, however, conveying especial information of this description, each quarry has its own version to give of the chapter of geological history that it illustrates; just as each copy of an ancient work will have its different readings and renderings of certain passages, whilst they all agree in the main facts stated.

How the geologists manage to coax—or rather to hammer—sermons out of stones is to some a profound mystery; whilst others treat the whole matter with the most supreme contempt, for to them a stone is merely a stone, and a quarry a pit in which men are at work cutting out and carting off the rocks for various purposes. Passing by these latter, we will ask our mystified friends to accompany us by that safest and most easy method of transit, a flight of imagination, to the nearest quarry, where we will endeavour to initiate them into the secret of "how to read the great stone book of Nature." The same means that conveyed us to the quarry has also furnished us with the requisite apparatus for pursuing our investigations—namely, a hammer, with one end of the head flat and square, and the other produced into a pick; a cold chisel, a pocket lens, a compass, a bottle containing acid, and a bag in which to put any specimens that we may wish to carry away with us.

As we stand thus equipped looking at the wall of the quarry which faces us, the first thing we notice is, that it is built up of a series of beds or "strata" resting one on the top of the other. Of these, the two uppermost are nearly horizontal, and for the present may be left out of the question. The rest are inclined at a

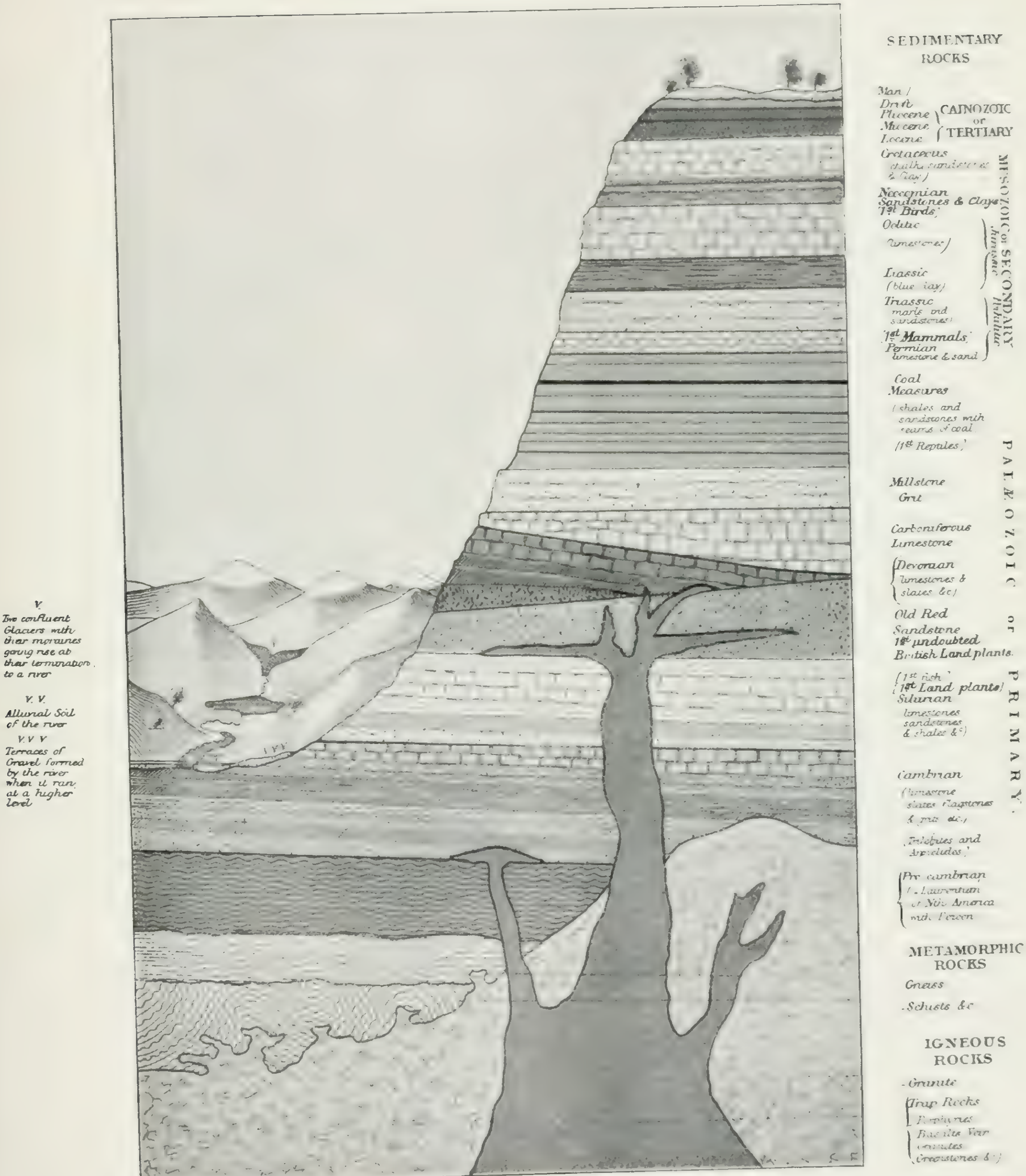


FIG. 1.—THE VARIOUS STRATA IN A QUARRY, SHOWN IN SECTION.

The diagram shows the position of one stratum relative to another, and the way in which the crust of the earth is made up of numerous superimposed strata, with special reference to Great Britain

considerable angle, and slope down to the left. Consulting the compass, we find that we are looking almost due west, and that the beds slope down—or, to speak geologically, "dip"—to the south. The necessary result of this dip in the strata will be to cause the beds which are at the bottom here to come to the surface a little further north; and, on the other hand, to the south we should expect to find other and newer beds coming in and resting on the top of these. The accompanying illustration (Fig. 2) will help to make this clear. Originally, of course, they were all horizontal, that being the position in which they were deposited; but afterwards, owing to movements taking place in the crust of the earth, they were tilted up as we now see them. Had it not been, therefore, for disturbances of this kind bringing the underlying rocks to the surface, none but the newest would be within our reach; whilst of the oldest geological formations now well known to us—as, for instance, the Silurian and Cambrian—we should have known absolutely nothing.

The next thing in the "section" that strikes the eye is a large crack running down in a vertical direction through these inclined beds, which at first sight appear to terminate abruptly on reaching it, for they have evidently no connection whatever with those immediately opposite to them on the other side of the fissure. A second glance, however, shows us that the same series of deposits occurs on each side of it, but that the relative level of the beds differs, those on the northern side of the fissure being some feet lower than the corresponding ones on the southern side.

FIG. 2.—SHOWING THE STRATA MET WITH IN A QUARRY.

A. Pure white limestone. *B. A bed of flints.* *C. Fine sand* *D. Rounded, black flints.* *E. Black clay.* *F. Light brown clay.* *G. More pebbles.* *I. Dark brown clay.*

FIG. 3.—A SEA URCHIN (*MICRASTER CORANGUINUM*)
From the chalk.

It is perfectly clear that they must formerly have been continuous, and that subsequently they were fractured at this point, and the northern set let down some eight or ten feet, bringing with it a portion of a higher bed (*i*), of which we should otherwise have had no trace in this section.

Dislocations of this kind are termed "faults"; they are of common occurrence, and in some cases the vertical displacement of the beds can be measured by as many yards as inches in the present instance. They also give rise to striking physical features, as they afford lines of weakness along which the rains and frost can act and cut out valleys for rivers to run in.*

But we have been stopping long enough at the entrance. Let us now make our way down to the section and see what all these different beds are made of, and what is the history that each has to tell us.

FIG. 4.—A BELEMNITE RESTORED.
(*After Zittel.*)
The chambered portions of the periostracum, which, with the guard, make up the internal shell, are indicated by dotted lines.

* CASSELL'S POPULAR SCIENCE, Vol. I., p. 93.

The bottom bed (*a*) you will recognise at once. A pure white limestone, with layers of flint nodules at tolerably regular intervals, it can only be the well-known chalk. Microscopic examination has shown that the chalk is almost entirely composed of myriads of minute shells belonging to small beings, low down in the scale of life, known as *rhizopoda* or *foraminifera*. Now, these same little rhizopods swarm in the Atlantic Ocean at the present day, and their dead shells are forming at the bottom of that ocean a deposit precisely similar to the chalk, to which we are therefore perfectly justified in ascribing a like origin. The way in which the flints were formed is still a moot point; but the most probable explanation appears to be that the water of the chalk sea every now and again accumulated more flinty matter in solution than it could hold, and was therefore compelled to part with it, which it did by precipitating it to the bottom, where, when there was sufficient, it spread out in vast sheets; more generally, however, the flinty material collected in nodules around any decomposing organic matter that lay half-buried in the soft sediment, towards which it was attracted by certain chemical laws. And this is the reason that fossils are so often found embedded in flint. Numerous fossils also occur scattered throughout the chalk—lamp-shells, sea-urchins, star-fishes, sharks' teeth, etc. One of the quarry-men is coming towards us with a hat full of these fossils; they pick out those they come across in the course of their work, and

FIG. 5.—A SHARK'S TOOTH.
From the chalk. The species of shark to which this tooth belonged is now extinct.

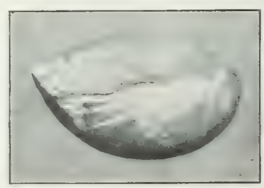


FIG. 6.—A LAMP-SHELL (*TEREBRATULA*).
From the chalk at Betchworth.

take the earliest opportunity of selling them. Here are two of the commoner forms of the *echinoderms* or sea-urchins (Fig. 3), and here is a shark's tooth (Fig. 5). The fossil you hold in your hand is a "belemnite" (Figs. 4 and 14); it is part of the internal bone, or pen, of a species of cuttlefish that lived in the chalk sea. The country people call them "thunder-picks," or "thunderbolts." Having picked out what we want of these, together with some specimens of the lamp-shells (Figs. 6 and 7), we will wrap them carefully in paper to prevent their rubbing together, put them into a bag, and then continue our exploration of the section.

The upper surface of the chalk, we find, is not perfectly even, but is worn into slight hollows; and resting on this slightly uneven surface is a bed of flints (*b*), about one foot thick. You can see that they have been washed out of the chalk; still, they do not seem to have been much rubbed, and therefore cannot have been carried far; but they nevertheless represent several feet of chalk entirely removed, so that a kind of gap exists between the chalk and the overlying deposits. It is not so great a break as one we shall come to presently, but, still, there it is, indicating that some disturbance or other took place in the physical conditions at this point, the results of which will be shown in the changed nature of the overlying beds. Trifling as it appears to the eye, this break is one of great importance; for, if you will consult the table of strata in Fig. 1, you will find that with the chalk the "secondary" rocks end; so that at this point we pass from one great division of the earth's strata to another, and at the same time from one great group of fossils to another, in which the forms of life are much nearer to those of the present day.

Resting on this bed of flints is a deposit of fine, light-coloured sand (*c*). It affords no trace of a fossil, and if any shells were ever buried in it, they probably disappeared long ago, as beds of this sort allow the rain-water to percolate through them. Now, as rain-water generally contains some amount of carbonic acid gas, which, although a weak acid, has the power common to acids generally of acting upon lime, the shells have been dissolved, so that, unless the sand is pretty firm, not even a cast of them is left. Yet, from the appearance of the sand itself, we can tell that it is a marine deposit formed at no great distance from land.

The next bed (*d*) we find to consist of rounded black flint-pebbles, packed closely together, the interstices being filled with sand. These pebbles have a

FIG. 7.—LAMP-SHELL (*TEREBRATULA*), SHOWING TOP VIEW.
From the chalk at Betchworth.

rough bedding, or "stratification," of their own, which runs at all angles to the direction of the bed itself, crossing it sometimes in one direction and sometimes in another, and giving rise to the appearance known as "false bedding." Now, in a sea beach the stones are of all sizes and shapes. Some are freshly broken, others are slightly rolled, the sharp edges being just worn off, and so on down to those that are quite smooth and perfectly rounded. But in this deposit all have been reduced to the kidney-bean shape, so that this is not a mere beach deposit, but must have formed a shingle bank a little way out to sea, in reaching which all the pebbles would get thus rounded and ground down. The appearance of "false bedding" is due to the action of the waves and currents that piled them up. See, here is a shark's tooth amongst them; so those voracious creatures could not

have been far off at the time! We shall, however, be hardly likely to find much else there, so we will proceed without further delay to the next bed.

This is a mass of black clay (*e*). On the outer surface it has, by exposure to the weather, become hard and dry, but it remains quite moist and plastic beneath. From top to bottom it is full of shells arranged in layers. As the clay is impervious to the passage of water these shells are capitally preserved, except on the outer surface of the bed, where they have been subjected to the destroying action of rains and frosts. Some good specimens are easily procurable, and by packing them in a box with some dry sand we can convey them home in safety.

The shells shown in Figs. 7–11 belong to the class of molluscs that love to dwell in the mud at the mouths of large rivers, where the water is brackish. The clay, too, is exactly such as would be formed from the fine sediment brought down by some large river to the sea, and there deposited on the bottom. Hence we infer that this bed of clay is nothing more than the dried and pressed down mud of some ancient estuary, whose turbid waters flowed over this spot in bygone ages. Before passing on, however, we must pause a minute to notice a ridge that juts out about the middle of this deposit, and is continued along its entire length. A tap of the hammer soon reveals its nature. Packed as closely as possible, and dovetailing, so to speak, into each other so as to form a hard band, are countless shells of oysters. As oysters like salter water than the other shell fish, they point to a slight change in the physical conditions at this stage, whereby the sea was enabled to gain slightly over the river, driving the estuarine shells back and allowing the oysters to settle here, till a return of the previous conditions re-established the former occupants in their old quarters.

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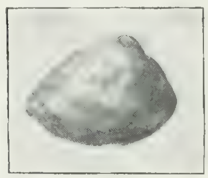

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FIGS. 7–11.—SHELLS FREQUENTLY FOUND IN QUARRIES, ALL DEMONSTRATING THE PRESENCE OF THE SEA AT THESE SPOTS IN SOME REMOTE PERIOD OF THE WORLD'S HISTORY.

7. Melania inquinata, from the Lower Tertiaries; 8. Cyrena semistriata, internal view, from the Bembridge Beds, Isle of Wight; 9. The same shell, external view. 10 and 11, Melania acuta, from Bembridge Beds, Isle of Wight.

A somewhat different state of affairs is denoted by the succeeding formation (*f*). It is also a clay—very sandy, with thin seams or "partings" of pure clay. Its general colour is light brown, and no shells are visible in it. By breaking off masses and splitting them along the seams, the surfaces thus opened display a number of darker brown marks, which, when examined with the pocket lens, prove to be vegetable matter.

Small stems and the seeds of water plants are abundant, whilst careful search is rewarded by the discovery of the perfect leaves of trees, which, if not identical with, are closely allied to, some existing forms. The sandy nature of the deposit and the presence of these vegetable remains lead us to suppose that it accumulated nearer to the shore than the last, in quiet and tolerably shallow waters, out of the main current of some river. This stream was probably the same as that which furnished the black mud for the underlying bed,

and, by this time, had, owing to the seaward advance of the land, to carry its finer sediments further down, and only left here the heavier particles of mud and sand and the waterlogged twigs and leaves of trees. At one period, however, the waters must have receded, leaving a swamp or marsh, in which various kinds of plants grew in abundance; for near the bottom of this bed appears a dark seam of "lignite," as it is called. If you examine a piece of this lignite under the lens, you will find that, like coal, it is entirely made up of vegetable remains pressed close together. Now, when vegetable matter buried in the earth is kept moist and the air excluded, it commences to decompose slowly, and gives off carbonic-acid gas. By this means it becomes gradually converted into lignite, and when this process of decomposition continues, the lignite is changed by degrees into common coal. We see that the lignite is merely coal in an early stage of its formation.

FIG. 12. — A CRYSTAL OF SELENITE.

From the Kimmeridge clay, Shotover Hill, Oxford. (Selenite is crystalline sulphate of lime.)

Succeeding this sandy clay with plant remains is another pebble bed (*g*), similar to the one we passed a little lower down, only the pebbles are much larger and more oval in shape, showing that this shingle bank was nearer the shore than the other. Here, too, amongst the stones at the bottom, are some shells of the same type as those in the black clay. A fresh inroad of the sea must, therefore, have taken place, and a shingle bank been formed off the mouth of the river.

Above this, again, is the formation (*h*) which, as we had occasion to observe, was preserved to us through the occurrence of the fault at this spot. It is a dark brown clay, dry and crumbly on the outside, becoming darker in colour and stiffer as you dig into it. That whitish, translucent substance that you have just picked out of it is the mineral called "selenite" (Fig. 12). A navvy would tell you that it was water "congealed by the moon"; it really is the crystalline form of sulphate of lime, and the crystals occur in clusters, radiating from a centre, falling apart when you attempt to excavate them. These clusters are all that remain of the fossil shells, once imbedded in the clay, that have undergone chemical change and passed into this new form. You can readily split selenite with a knife, in one direction, into slices as thin as paper; but try and cut it in a direction perpendicular to this "cleavage plane," as it is termed, and you will not be able to force the blade through it.

Only the two topmost layers now remain to be considered. These, as we saw before, are not affected by the "fault," nor do they dip to the south like the underlying strata, but rest in an almost horizontal position on the upturned edges of the latter, which in places are worn into great hollows. A considerable period of time must therefore have elapsed between the deposition of the underlying beds and

FIG. 13.—A FLINT AND THE FOSSIL SPONGE CONTAINED IN IT.

From the chalk, Cookham Dene.

these two upper ones : a period sufficient to allow of the former being tilted up and "faulted," and the surface of the ground levelled before the latter were thrown down on them, all of which movements were effected by slow degrees, and not by any violent convulsions of Nature.

In order to get some idea of the length of time thus consumed, it will be necessary to ascertain in the first place the geological age of the underlying inclined beds, and then that of the two horizontal ones.

Now, the sands, gravels, and clays which we have just been examining overlie the chalk, and are therefore newer than it. The chalk, we learned, was the uppermost bed of the "secondary" series, so that these sands, etc., must be of "tertiary" age. The fossils they contain inform us that they belong to the lower portion of the lowest division of the tertiary series ; a conclusion which we might have expected, though it did not of necessity follow, from their position with regard to the chalk. So much, then, for our first point. Now for the second—the age of the topmost beds. To solve this, we must ascertain what they are, and inquire somewhat into their history.

The lower of the two (*i*) is clearly a gravel, and the upper (*k*) a clay full of big stones. The gravel is very different from the pebble beds we saw just now. Instead of rounded flint-pebbles, it consists mainly of angular stones, and, while most of them are flints, there are also great numbers of other stones derived from rocks of altogether a different sort to those found round about here. Furthermore, they exhibit no sign of being spread out by water action ; there is no trace of any stratification whatever ; they lie all jumbled together "anyhow," with here and there a mass of sand let in bodily.

A similar want of arrangement characterises the clay ; there are no layers in it ; it is one uniform mass from top to bottom ; the big stones are scattered promiscuously throughout it in all sorts of positions ; and it is so full of pieces of chalk, from the size of a hen's egg down to the smallest imaginable grains, that it has a whitish tinge. Break open some of these big stones or "boulders," and you will find that they are fragments of many different rocks. There are granites, basalts, and limestones of all ages. You can tell the limestones in a minute, for they can be scratched with a knife, and a drop of acid put on them begins immediately to "fiz." Many of these boulders are flattened and smoothed on one side, and covered over with long parallel scratches.

What, then, can have produced all these several results ? And how were all these various stones brought together ? There is only one agent known that could have performed all this work ; that agent is—ice.

The sand and gravel were floated hither from some sea beach, frozen in blocks of coast ice, which, stranding and melting, deposited them at this spot ; the boulders, detached by frosts and snows from their parent rocks, were smoothed and scratched by being fixed in masses of ice and ground against other rocks : ultimately they were floated down here on icebergs, and dropped into the glacial mud, which itself was formed by the wearing action of divers forms of ice upon the land.

FIG. 14. — A BELEMNITE (*BELEMNITELLA LÆVIS*). *From the Lias at Whitby.*

To geologists these beds are known as "drift," and, with the exception of the valley gravels and alluvium, they are the most recent of the sedimentary rocks, as you will see by referring once more to the table of strata shown in Fig. 1.

We have thus solved our second problem, and are now in a position to gain some notion of the immense break in time between these glacial drifts and the strata they

rest on in this quarry. It cannot be estimated in years, or even hundreds of years, for it is impossible to form any accurate conception of the rate at which any given deposit accumulates; but we may be able to form some faint idea of its vastness when we realise the fact that this gap is elsewhere filled by beds some hundreds of feet in thickness, belonging to the Miocene and Pliocene epochs; that the great mountain ranges of Europe attained their present elevations by receiving an additional upheaval of several hundred feet; and, finally, that all the main physical features of the country were marked out in this interval, during the greater part of which this spot was, perhaps, dry land.

Here the record of the rocks in this quarry terminates. The neighbouring river takes it up and carries it on down to the present date; it could tell of the rude savages who dwelt on its banks in prehistoric times, and fashioned weapons of flint and stone, with which they fought or hunted the huge wild animals that roamed about. With these, however, we have on the present occasion nothing to do, and so turn homewards, laden, it is to be hoped, with some additional weight of knowledge, as well as the more tangible burden of fossils for the cabinet; reflecting by the way on the things we have learnt from this visit to a quarry: How that the past history of our earth, as related by geologists, so far from being a mere baseless myth, is a true account, founded on sound reasoning, and only to be learned by a diligent study of the phenomena in constant operation around us, and a careful application of the knowledge thus derived to the facts furnished by the various deposits—a process not more mysterious than the train of arithmetical reasoning by which we ascertain that two and two make four. We learn that the ground beneath us must have been formed at the bottom of sea, lake, and river, the particles of which it is composed being the results of the wearing away of some still older land surface by the agencies of rain, frost, wind, etc., and the transporting powers of running water and floating ice. And now, when we next chance to light on a quarry of any description, instead of simply speculating as to the origin of the rocks we see in it, we may be able to set practically to work to obtain the information we desire concerning them.

* The reader who desires to make a further study of the subject with which this article deals should read Prof. Bonney's "The Story of Our Planet" and "Charles Lyell and Modern Geology" in the "Century Science Series."

FIG. 15.—AN AMMONITE.

HOW GLACIERS MOVE.

WE have seen* that a glacier is a river of snow compacted into ice, and how, in the course of its slow journey from the region of perpetual snow, it exhibits phenomena of wonderful interest. But of all these phenomena the mere fact of its motion is not the least remarkable—that a seemingly solid, hard, brittle river of ice should pass from the upper Alpine regions down into the valleys among the vineyards, or in the Arctic regions to the sea, accommodating itself to all the inequalities of the ground, and in nearly every respect behaving just as if it were a river of water.

That the glacier possessed some kind of vital agency used to be a current belief among the peasantry of the Alpine valleys, a belief that arose from the fact that foreign bodies, such as large stones, dropped into a crevasse, were found rejected, after weeks or months, by the glacier. This apparent rejection of bodies was proved by M. Agassiz, who placed plugs of wood at various depths in a hole dug for the purpose in a glacier. These plugs were successively discharged, according to their situation in the hole. The rejection of foreign substances by the glacier is, however, only apparent; they remain in their original position, but, the surface ice of a glacier being in a constant state of liquefaction, the ice is gradually melted to the level of these bodies, and they then become visible on the surface. Many other illustrations of this glacial "ejection" might be given. One or two examples will show the use that may also be made of them in calculating the rate of motion of a glacier.

An Alpine guide, named Contet, found in 1846 fragments of a knapsack which had been lost ten years previously in a deep crevasse; the contents were undestroyed, and formed a certain means of recognition. They were found on the surface of the glacier 4,300 feet lower down than the spot where they had been lost, giving an annual movement of 430 feet. The space travelled over includes a spot where the ice is dashed over a rapid 1,000 feet high. Again, in the highest part of a glacier near Chamouni, a sudden and noiseless descent of snow carried over a precipice, and buried, the leaders of a party ascending Mont Blanc. This was in 1820, and happened only 1,000 feet from the summit of Mont Blanc—at a height, that is, of 14,784 feet. In 1861 some guides, while crossing the lower part of this glacier, found bones, skulls, knapsacks, and other traces of this party. This was at a height of only 4,400 feet; the descent, therefore, in forty-one years was 10,384 feet, equal to 253.26 feet a year.

This must not be taken as the maximum of speed attained by one of these ice-rivers, for, according to Helland, the Jacobshafn glacier, in Greenland, moved from 48·2 to 64·8 feet per diem. Dr. Rink was of opinion, after he had made many experiments and obtained a mass of information, that 21 feet in 24 hours was the average of the most lively glacier. Between this rate of advance and the nearly stationary there are many degrees of variance, while some of the Greenland glaciers are very nearly at a standstill. The measurements and observations made by Dr. Forbes in the Mer de Glace, Chamouni, showed that in summer and autumn the glacier's daily progress was at the rate of from 1 foot 8 inches to 2 feet 3 inches in the centre, and from 1 foot 1 inch to 1 foot $7\frac{1}{2}$ inches at the sides.

* CASSELL'S POPULAR SCIENCE, Vol. I., p. 94.

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A TYPICAL SWISS GLACIER THE MER DE GLACE.

It is well known that a river of water moves faster in the middle than it does at the sides, and the river of ice does not differ in this respect from the river of water.

But the question remains, How can a solid and brittle substance like ice behave like a liquid, flowing down gentle slopes and accommodating itself to its bed? There have been many attempts made by scientific men to explain the river-like motion of glaciers. The valleys in which glaciers lie are always inclined, and this led De Saussure to suggest that the weight of a glacier was sufficient to urge it down the slope, the accumulated snow above pressing it downwards, the motion being aided by the assumed liquefaction of the ice on the under surface of the glacier from the natural heat of the earth. But this "sliding theory" is not only insufficient to explain the liquid-like motion of a glacier, it is obviously inconsistent with facts; for, among other reasons, even if the channel were perfectly smooth, instead of having, as is the case, an uneven and rocky surface, no *solid* and therefore rigid body would slide down unless the slope were much greater than it generally is in the glacier valleys. The accompanying diagram (Fig. 1), drawn to scale from Forbes' observations, will give some idea of the gentle slope of a glacier.

Another theory, proposed by De Charpentier, was to the effect that the glacier was pushed down by the force of expansion arising from the freezing of water. The body of the glacier was supposed to be penetrated with minute fissures, which filled with water in the day and were frozen at night; and, as water expands in freezing, this process, being constantly repeated, was supposed to account for the motion of the glacier. But this "dilatation" theory is still less in accordance with facts than the previous one; for in winter the glacier ought not, according to this explanation, to move at all, whereas it does. Moreover, the changes of temperature between night and day are felt only to a very small depth below the surface of a badly conducting body like ice; and, finally, there is no evidence to show that a glacier is penetrated with minute fissures.

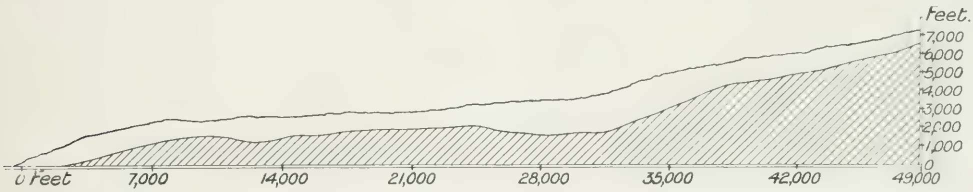

FIG. 1.—SECTIONAL VIEW OF THE MER DE GLACE FROM THE SOURCE OF THE ARVEIRON (0′) TO THE COL DU GÉANT (7,000′).

After measurements given by Professor Forbes. The figures represent feet.

This was the state of knowledge on the subject when the late Principal Forbes began his glacier observations, which led to the publication of his "Travels in the Alps." Forbes first set to work to obtain accurate data, and the observations he made in 1842 he has thus summed up:—

(1) That the downward motion of the ice from the mountains towards the valleys is a continuous and regular motion, going on day and night, without starts or stops.

(2) That it occurs in winter as well as in summer, though less in amount.

(3) That it varies at all times with the temperature, being less in cold than in hot weather.

(4) That rain and melting snow tend to accelerate the glacier motion.

(5) That the *centre* of the glacier moves faster than the sides, as is the case in a river.

(6) That the *surface* of the glacier moves faster than the bottom, also as in a river.

(7) That the glacier moves fastest (other things being supposed alike) on steep inclinations.

(8) That the motion of a glacier is not prevented, nor its continuity hindered, by contractions of the rocky channel in which it moves, nor by the inequalities of its bed.

(9) That the crevasses (Fig. 2) are for the most part formed anew annually, the old ones disappearing by the *collapse* of the ice during and after the hot season.

The consideration of these facts led Forbes to the conviction that the ice of a glacier behaved, not as a rigid body, like stone, but as a plastic or viscous body, more like dough or thick honey, though of course less fluid, and therefore less mobile, than these bodies. Now, a solid and a viscous body behave very differently on a gentle slope—the former moves as a whole, the latter has a movement of its parts analogous to a liquid. A mass of pitch will, after some time, spread itself over the surface on which it rests, through the continual action of gravity. According to Forbes, melting ice is a body of this kind, hence the gradual creeping of a glacier down into the lower valleys.* This theory he clearly states in the following passage :—" A glacier is a plastic mass impelled by gravity, having tenacity sufficient to mould itself upon the obstacles which it encounters, and to permit one portion to slide past another without fracture, except when the forces are so violent as to produce discontinuity, in the form of a crevasse, or more generally of a bruised condition of the mass so acted upon ; that, in consequence, the motion of such a mass on a great scale resembles that of a river, allowance being made for almost incomparably greater viscosity : hence the retardation of the sides and bottom. Finally, that diminution of temperature, diminishing the plasticity of the ice, and also destroying the hydrostatic pressure of the water which fills every pore in summer, retards its motion, whilst warmth and wet produce a contrary effect."

This " viscous theory " subsequently met with vigorous opposition on the part of Professor Tyndall, who contended that ice, even at the melting point, was a rigid crystalline body, incapable of flexure, and therefore unable to flow and to mould itself to its channel. Dr. Tyndall thereupon proposed another explanation, based on the curious property possessed by thawing ice—namely, the freezing together of those surfaces which are in contact. This property was first carefully examined by Faraday, and named by him *regelation.* It can be observed any day in the fragments of ice at a fishmonger's shop. It is familiar to everyone in the manufacture of a snowball ; and it is by regelation that the " snow bridges " are formed which often span the yawning chasms in the Alps. It is simply necessary to bring two fragments of ice into contact with each other, when they will immediately become cemented together. This, however, will be found to occur only with thawing ice—that is, with ice at its melting point—the surface of which is therefore covered with a film of water. If the experiment be tried upon a very cold day, when the thermometer stands some degrees below freezing point, it will not succeed. Nor can a snowball be made under such conditions ; even if vigorously squeezed, it still remains a loose, incoherent powder. Both in the snow and the ice an exterior

* The term *viscosity* has been defined by Professor Tait as "an internal resistance to change of shape, depending on the rapidity of the change," and therefore expressing "molecular friction," which, in a less degree, exists in fluids, both liquid and gaseous, and in these bodies is generally known as the "viscosity of fluids." Frictional resistance to change of shape is not, however, quite the sense in which Forbes used the word viscosity, but rather the gradual yielding of the shape of a body under continued stress, to which the word *plastic* may more strictly be applied, thus embracing semi-solid and semi-liquid substances like mortar.

FIG. 2. CREVASSES IN THE MER DE GLACE.

These crevasses are frequently spanned by snow bridges, the deceptive appearance of which has been the direct cause of many an Alpine disaster.

film of water is necessary, for it is the freezing of this film which glues the fragments of ice or particles of snow together.

The cause of this regelation we shall study directly. The fact of it occurring does undoubtedly account for the conversion of the discontinuous névé into the continuous ice of the glacier. Professor Tyndall, however, went further. This distinguished physicist and Alpine traveller sought in regelation, as we have said, an explanation of the behaviour of a glacier, the mobility of which, he asserted, was apparent—not real. According to this theory, the ice is incessantly being broken and crushed by the strains and stresses to which it is subject; but, after it has broken, regelation sets, in, heals the wounds, and binds the ice once more into a continuous whole. By some interesting experiments on moulding crushed ice into various shapes, through the pressure exerted by an hydraulic press, Dr. Tyndall supported his theory of "fracture and regelation." The accompanying figures will show the shapes which ice can be made to assume by simply squeezing broken fragments powerfully together. Into an iron mould, shown partly in section in Fig. 3, crushed ice or snow is rammed; the solid piston is then forcibly driven home, and a little cylinder of clear ice is produced. In like manner, the boxwood mould in Fig. 4, shaped like a cup and ball, is able to produce a cup of ice, and another mould a disc of ice. Placing these parts in contact, regelation sets in, and freezes the whole together into a claret-glass, as shown in Fig. 5. When a Bramah press is not at hand, a large vice may be successfully used in making the foregoing pretty experiment. Magnify these moulds—as the eminent Swiss naturalist M. de la Rive has remarked—and they become the borders of the valley through which a glacier flows: the weight of the snow and ice above takes the place of hydraulic pressure; and gravity, incessantly in operation, causes the ice insensibly to accommodate its form to that of the valley. Thus ice seems to exhibit a plasticity like soft wax. But ice, the same writer continues, is plastic only under pressure—not under tension. This is the main fact on which the advocates of the fracture theory rely. Time and temperature are, however, overlooked, and the introduction of these elements changes the aspect of the case. Let us, therefore, look at the two theories in the light of recent experiments on ice.

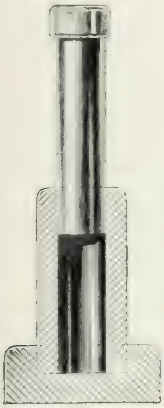

FIG. 3.—SECTION OF IRON MOULD WITH PISTON USED FOR COMPRESSING ICE.

Forbes' theory of glacier motion, as we have seen, rests upon the assumption that ice at its melting point is essentially a plastic body, and, like warmed sealing-wax, will bend in response to a gentle continuous pressure, though it will snap under a great and sudden strain. On the other hand, Tyndall's theory is based on precisely the opposite assumption: that ice is not plastic but crystalline in its structure, and brittle in its behaviour. Careful experiments on the possibility of bending ice have been made. Canon Mozley, Mr. Mathews, and others have shown that an ice-plank at the melting point *does* gradually bend under pressure,

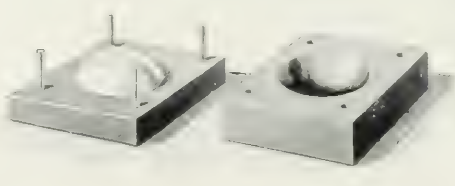

FIG 4.—BOXWOOD MOULD FOR SUBJECTING ICE TO PRESSURE.
Note to the left the ball of ice that has been formed.

like a plastic body. More recent experiments made on the Continent by Bianconi corroborate this fact, thus proving that ice has a certain degree of plasticity, notwithstanding its brittleness. The ice-plank, though it can be bent by gradual pressure, is shattered to pieces

FIG. 5.—CUP OF ICE (A) FORMED BY SQUEEZING TOGETHER THE PARTS (B) MADE BY THE MOULDS IN FIGS. 3 AND 4.

by a slight shock. M. Bianconi has also shown that pebbles and other solid bodies can be pressed into the ice, penetrating it as they would a semi-fluid body, the particles of ice rising up in a ring around the intruded body. Another Continental physicist, Herr Pfaff, has ascertained the *amount* of pressure necessary to displace the particles of ice, and has proved that even the smallest pressure acting continuously is sufficient for this purpose if the ice and its surroundings are kept approximately at the melting point. Under a pressure of two atmospheres—say 30 lb. on the square inch—the ice, even at one degree below its freezing point, showed itself so yielding that a little hollow iron cylinder, half an inch in diameter, sank an eighth of an inch into the ice in a couple of hours. When, however, the temperature was four or five degrees lower, the cylinder penetrated the ice only one-sixteenth of an inch in twelve hours; and when the temperature was reduced to 18° Fahr. below the freezing point, the cylinder almost refused to enter the ice, penetrating only one-twenty-fifth of an inch in five days under a pressure of five atmospheres. In like manner the same observer has shown that an ice-plank suffers a scarcely sensible bending when the temperature is much below the freezing point, but that as soon as the temperature rose the bending was most marked and rapid, yet nowhere could the least trace of a crack be discovered.

These important experiments, which quite corroborate the opinions held by Forbes, based on observations long since made by M. Persoz, establish the fact that cold ice is a brittle, non-plastic body, but that ice near its melting point is a yielding, plastic body. It only remains, therefore, to ascertain the internal temperature of a glacier, both in summer and in winter—for, as already stated, the motion goes on in winter. Then, if the temperature be found very much below the freezing point, the viscous theory must be given up. If, on the other hand, the temperature be found at or near its melting point, the fracture theory must be relinquished as unnecessary and less in accordance with the observed facts of glacier motion.

Thermometers have been sunk deep in the ice of a glacier, and careful observations made of the temperature of the ice at various seasons in the year. In every case the internal ice has been found close to its melting point. At the bottom of a hole bored 200 feet deep in the solid ice the temperature in summer was found to be $31\frac{1}{4}°$ Fahr., the melting point being 32°; and in winter time in the same hole it was $28\frac{1}{4}°$ Fahr., this being an exceptionally low temperature. The swifter motion of the glacier in summer is thus readily accounted for. The streams of water—arising from the snow and ice melted on the surface—which during the summer everywhere penetrate a glacier, raise its temperature to the melting point; and in winter,

when these streams cease to flow and hard frosts set in, the extremely low conducting power of ice for heat preserves the whole of the glacier, except its superficial portions, at a temperature little below the freezing point. Knowing these facts, it is difficult to withstand the conclusion that the viscous theory maintained by Forbes is a true interpretation of the flow of a glacier.

We need not do more than allude to the theory proposed by Dr. James Croll, which supposes a molecular motion of the ice. Here it is assumed that a progressive liquefaction of the ice particles takes place owing to the transmission of heat through the ice. This theory, however, breaks down from one fact, among others, that ice is not a conductor of heat, as assumed by Dr. Croll, though radiant heat is to a slight extent capable of traversing it. Radiation and conduction are, however, different things.

Having thus discussed the various theories of glacier motion, let us, in conclusion, endeavour to understand that beautiful process of refreezing, or *regelation*, whereby the ice of a glacier continues a compact mass in spite of its perpetual movement and numerous fractures. The explanation of regelation, like the cause of glacier motion, has given rise to considerable diversity of opinion. Faraday viewed the action somewhat in this way:—A greater freedom of motion is enjoyed by a liquid than a solid; this freedom is first gained by the water at the surface of the ice, for here the particles are bounded on one side only by the solid mass, and by the atmosphere on the other. Some

Photo: G. Wehrli, Kilchberg, Zurich.

FIG. 6.—THE ROTHTHAL GLACIER.

This is one of the branches of the Great Aletsch, the largest of the Swiss glaciers.

controlling action may be assumed to be exerted by the particles of the solid on the one side. When a second piece of ice touches the first, the layer of water is squeezed away at the points of contact to the thinnest possible film, and this film finds itself bounded by solid surfaces on both sides. "The liberty of liquidity," as Professor Tyndall puts it, "at each point where the surfaces touch each other is arrested, and the two pieces freeze together at those points." In this explanation it is difficult to account for the escape of the heat which is liberated by the passage of the water into solid ice. This difficulty is got rid of by regarding the interior of the block of ice as colder than the exterior, the heat diffusing itself by conduction into the mass.

Experiment shows that the interior of a block of ice *is* slightly colder than the exterior, and upon this fact Professor Forbes founded a different and fuller explanation of regelation. The surfaces of two blocks of melting ice which are brought together are virtually transferred from the exterior to the interior. The ice on both sides of the enclosed layer of water will now be colder than the water, and a new distribution of heat accordingly takes place, the result of which is that the water is frozen, as it is now in the central, and therefore coldest, part of the block.

A third explanation of regelation has been given by Professor James and Sir William Thomson, founded upon the important fact, which they first established, that the temperature at which water freezes may be slightly lowered by strong pressure. According to Sir William Thomson's calculation, the melting point of ice is lowered by pressure at the rate of ·0074° Cent. per atmosphere of pressure. The pressure of the atmosphere is equivalent to one of 15 lb. per square inch. If, therefore, ice at its ordinary melting point—32° Fahr.—be squeezed, it tends to become liquid, and when considerable pressure is used liquid films may be seen within the ice. Upon the removal of the pressure the freezing point rises, and the liquid films again become ice. This action, according to the eminent philosophers just named, is sufficient to account for the fact of regelation. It may be urged, however, that the pressure is too slight for liquefaction by this agency to come into play. This objection may be met by supposing—what is doubtless actually the case—that under a feeble pressure the fragments of ice will only touch in a few—practically three—points, and upon these the whole of the pressure is concentrated; a feeble *total* pressure may, therefore, be a very considerable *local* pressure at the points of contact. Under this stress a trace of ice will melt, and on the removal of the pressure the water formed will freeze.

In the case of a glacier, the water produced between the pieces of ice which are pressed together can escape through the numerous cracks which penetrate the glacier; and as it runs away, not only does it escape the pressure, but it also carries with it the heat necessary for its liquefaction. Under these conditions the pressed ice becomes colder than zero, owing to the lowering of its freezing point by pressure, and this cold ice finds itself in contact with water at the zero temperature. The result is that a continual freezing of some of the escaping water takes place, new ice thus forming round the portions which are pressed, whilst these are simultaneously undergoing a slight superficial liquefaction. Thus Helmholtz has explained how the cementing of the masses of ice by regelation may occur even when the pressure is unrelaxed, provided that cracks exist in the ice to allow some motion to the liberated water.

Each of these rival theories has had eminent advocates. It is not improbable that all three causes are to some extent

operative, and that under particular conditions one or other comes more prominently into play. Broadly viewed, the theory of Forbes seems most consistent with observed facts.

Before bringing this necessarily brief talk on glaciers to a close, we must not omit (though unconnected with the subject of the present paper) a brief notice of a beautiful structure developed in ice when a beam of luminous heat is passed through a slab of ice, cut parallel to its plane of freezing. Exquisite six-sided stars are then seen forming within the ice; these are composed of water arising from the slow disintegration of the ice crystals. There is also a shining central spot, which is vacuous, as the bulk of the water is less than that of the ice from which it was derived. It is easy to witness for one's self this interesting phenomenon, first noticed by Dr. Tyndall. All that is necessary is to procure a block of ice, saw a slice parallel to the plane of freezing—which can generally be discerned by the air bubbles or by other means—smooth the sides by rubbing on a warm metal plate, hold the slab close to a lamp or gas flame, and during its liquefaction observe the ice, assisting the eye by a lens. The swift formation of the pretty six-petalled liquid flowers will then be instructively and distinctly seen. As might be expected, there is a striking resemblance between the general shape of these "ice flowers" and the lovely snow crystals* that are sometimes seen in such wonderful perfection. Indeed, few things in nature are so full of interest to the diligent student as water, whether as solid, liquid, or vapour. And so every familiar object has its tale to tell, and will yield untold pleasure and unsuspected wonders to the patient inquirer.

* *See* the article on "Snow," Vol. I., p. 140; also Prof. Bonney's "The Story of Our Planet."

FIG. 7.—SUMMIT OF MONT BLANC, 15.784 FEET ABOVE SEA LEVEL, SHOWING CAP OF ETERNAL SNOW.

HOW TO MAKE A CHEMICAL ANALYSIS.

THE combustion of gases, the spontaneous ignition of solids in air and in water, the beautiful transitions of colour produced by precipitation, the transformation of solids into liquids, and liquids into solids, the detonation of fulminates, the explosion of mixed gases, the smoke-rings of phosphuretted hydrogen, the symmetrical forms of crystallisation, and the wondrous revelations of the spectroscope, are some of the phenomena which have attracted many of our most eminent chemists to the study of a science in which they have afterwards gained so much distinction.

FIG. I.—THE FLAME TEST FOR OXYGEN.

A glowing splinter plunged into a vessel containing oxygen bursts into brilliant flame. This is what is taking place in the tube of oxygen held by the operator.

The determination of the constituents of a compound substance, and of the proportions in which such constituents exist, are operations which tax the chemist's resources and ingenuity to the utmost, and constitute a crucial test of his knowledge, care, and manipulative skill.

The candidates at all examinations of any importance in chemistry are required to give evidence, by means of paper work and oral examination, that they have a good theoretical knowledge of the subject.

In addition, they must also show ability to practically perform in the laboratory such tests as may be set, according to the particular requirements of the examiners. For this latter purpose a number of substances—such as metallic oxides and salts—are presented for analysis. Some of these salts (the composition of which is, of course, unknown to the candidate beforehand) are simple—that is to say, consist of one *acid* and one *base* only—while others are mixtures of several acids and bases. A knowledge of both *qualitative* and *quantitative* analysis may be required, according to the standard of the examination. The "quantitative," however, is only necessary in the case of some of the higher examinations, and so may be here neglected.

A substance is examined *qualitatively* when it is sought to ascertain the constituents which enter into its composition, without regard to their relative quantities; but when we wish to discover the weight or volume of such constituents, the analytical processes to be employed are of a different kind, and are termed *quantitative*. A quantitative analysis involves much greater manipulative difficulties, and requires to be conducted with much more care and exactitude than one which is simply qualitative; for the slightest loss or error in collecting, drying, or weighing the precipitates will sadly vitiate the

results. Some expertness in what may be called mathematical chemistry is also essential. The law of chemical equivalents, for example, furnishes the student with the means of calculating the proportions of acid and base in any given salt without actually isolating and weighing them.

The following will be found a very easy method for the analysis of a simple salt, which can be learnt in a few days by an intelligent student, who need not necessarily possess anything but a mere smattering of the science to enable him to practise it with success. By this method the "acids" and "bases" here named can be readily detected, provided that the salts to be analysed are pure and free from organic or other extraneous matter.

Bases.

Class I.—Potassium, Sodium, Ammonium.
,, II.—Barium, Strontium, Calcium.
,, III.—Manganese, Iron (protosalts), Magnesium, Cadmium, Bismuth.
,, IV.—Zinc, Tin (protosalts), Aluminium, Lead, Tin (persalts), Antimony.
,, V.—Mercury (protosalts).
,, VI.—Cobalt, Copper.
,, VII.—Nickel, Chromium, Iron (protosalts and persalts mixed).
,, VIII.—Mercury (persalts), Gold.
,, IX.—Iron (persalts), Silver.

Acids.

Class I.—Nitrates, Chlorates, Chlorides, Iodides, Arsenites, Sulphides.
,, II.—Fluorides, Phosphates, Arseniates, Borates, Oxalates.
,, III.—Carbonates.
,, IV.—Sulphates.
,, V.—Chromates.

Before commencing operations we must have at hand the following reagents in solution: — *Sodium carbonate*, *ammonia*, *caustic potash*, *potassium ferricyanide* (*red prussiate of potash*), and *sulphuretted hydrogen*. To make these solutions some of the simpler pieces of chemical apparatus are employed, of which the following are the most essential:—Three or four flat-bottomed glass flasks, varying from four to ten ounces in capacity; a few beakers of similar capacity, some glass stirrers, a small porcelain mortar and pestle, some platinum foil and wire, a pipette, a dozen large test-tubes, test-tube holder, two small retorts, retort stand, three feet of narrow glass tubing, glass funnel, filtering paper, red and blue litmus paper, and a spirit lamp or Bunsen burner. We are now in a position to prepare our reagents. To begin with the sodium carbonate, it is necessary to make a *saturated solution* to be preserved for testing purposes.

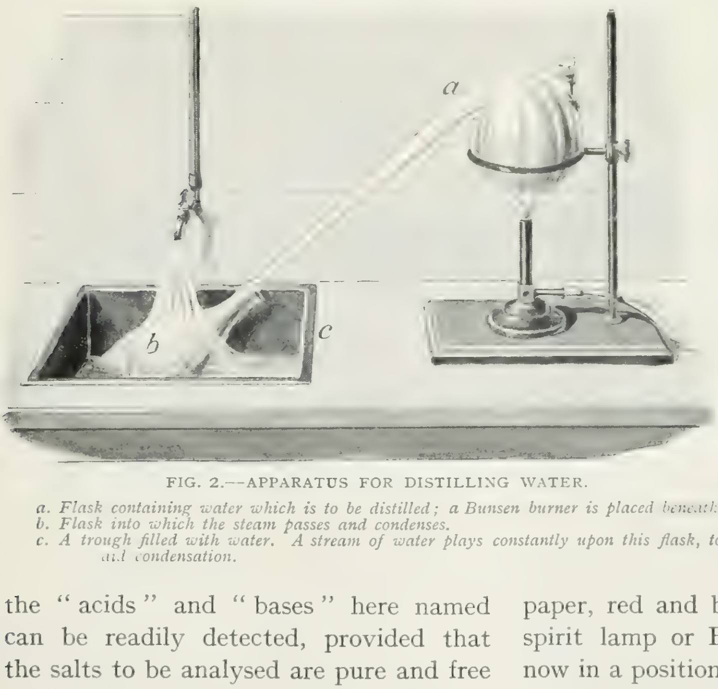

FIG. 2.—APPARATUS FOR DISTILLING WATER.

a. Flask containing water which is to be distilled; a Bunsen burner is placed beneath.
b. Flask into which the steam passes and condenses.
c. A trough filled with water. A stream of water plays constantly upon this flask, to aid condensation.

To prepare a saturated solution of any salt it is best to use boiling water, as more of the salt is likely to be taken up than if cold water is used, although this is not always the case. We will, then, select a flask capable of holding five or six ounces, and nearly fill it with distilled water. An ample supply of this water must be always in readiness, as no other can be used for

analytical purposes. Distilled water is prepared by boiling ordinary water, converting it into steam, and condensing the steam given off, which provides almost absolutely pure or, as it is termed, distilled water. An ordinary retort fitting into a bottle by way of receiver can be employed (Fig. 2). The bottle or flask into which the steam is passed must be kept cool, either by immersing it in a trough of cold water or allowing cold water from a tap to be continually running over it, so

FIG. 3.—GENERATING SULPHURETTED HYDROGEN.

a. The generating flask, fitted with safety funnel, and containing iron sulphide and dilute sulphuric acid; b, the flask in which the gas is "washed" or purified; c, flask in which the gas is taken up by the water.

that proper condensation may be effected. The distilled water sold by the druggists is often impure, owing to its having been carelessly prepared in an impure atmosphere charged with various gases. As distilled water that is old is very likely to be impure, it is always best for analytical purposes to use it freshly distilled, and never keep it for any considerable length of time. Distilled water can always be tested as to its purity. If it gives the slightest precipitate with *barium chloride* or *silver nitrate*, it must be rejected as containing salts of lime or traces of *sodium chloride*.

Having adjusted our flask upon the ring of the retort-stand, about two inches above the lamp, or Bunsen burner, which is far preferable, we heat the water, and add in small portions at a time the carbonate of soda previously reduced to a fine powder in the mortar. The powder should not be taken up with the fingers, but dropped into the flask from a folded piece of glazed writing-paper. The water is saturated when no more of the powder is dissolved after repeated stirring. Allow the solution to cool, and filter it into a stoppered bottle for use in subsequent operations. With regard to our second reagent—liquid ammonia—no preparation is necessary, as the saturated solution used in testing is kept in a sufficiently pure state by every chemist. The third reagent to be prepared is solution of caustic potash (*potassium hydroxide*). This is sold in the form of round sticks or irregular lumps, and the solution is made and saturated in the same way as our standard solution of sodium carbonate.

The solution of ferricyanide of potassium, or red prussiate of potash, is similarly prepared, but to make the solution of sulphuretted hydrogen we shall have to fit up the necessary apparatus for producing the gas and conducting it into the water to be saturated. Three flasks are employed for generating, washing, and collecting the gas (Fig. 3). In the first bottle the gas is produced by the action of dilute sulphuric acid upon iron sulphide; in the second bottle it is washed, or purified, by being allowed to pass through a small quantity of water; and, finally, in the third it is absorbed by the water, which takes up many times its own volume of the gas.

The reaction which takes place in the generation of the gas is as follows:—

$$\underset{\text{(Iron sulphide)}}{FeS} + \underset{\text{(Sulphuric acid)}}{H_2SO_4} = \underset{\text{(Iron sulphate)}}{FeSO_4} + \underset{\text{(Sulphuretted hydrogen.)}}{H_2S}$$

This solution of sulphuretted hydrogen is a very valuable test for many of the metals, with which it produces *sulphides* of characteristic colours. The stopper of the bottle in which it is kept must be replaced immediately after use, as the

solution decomposes by the action of the air, and becomes discoloured.

We are now ready to begin our analysis, and a simple salt, in crystal or in powder (the latter is the usual form, as being less recognisable), being handed to us for examination, we proceed to divide it into four portions. One of these portions serves for the detection of the base, another for the acid, and the remaining two are reserved for confirmatory tests. Having made a solution of the salt as strong as the quantity at our disposal will permit—presuming, of course, that it is soluble in water—we pour a small portion into a wide test-tube, and add, drop by drop, the solution of sodium carbonate. If we perceive no precipitate, especially after boiling, then we are to presume that there is present one of the metals in Class I. Which of them it is we now proceed to determine. Take a little of the dry salt, and mix with it an equal quantity of dry sodium carbonate, together with a few drops of water. Heat the mixture in a test-tube or small evaporating dish, and if the well-known pungent odour of ammonia is produced, then we are certain that the unknown salt contains the base *ammonium ;* but if not, we must proceed to discriminate between the remaining two metals—potassium and sodium. Take a little of the salt, and fix it in the loop of a platinum wire, and heat it in the blowpipe oxidising flame, as in Fig. 4. If a strong yellow colour is communicated to the flame, the metal present is *sodium ;* but if there is no change of colour, or a slight tinge of violet is perceived, the metal must be *potassium.* If the smallest trace of soda is present in a salt of potassium, the yellow colour alone will be observable in the flame. It is therefore advisable to employ two additional confirming tests.

To a concentrated solution of the salt add a drop of perchloride of platinum. A yellow crystalline precipitate indicates potassium, while no precipitate indicates sodium. To another portion of the concentrated solution add a few drops of a strong solution of *meta-antimoniate of potassium.* No precipitate indicates potassium, and a white crystalline precipitate, slowly formed, indicates sodium.

We have thus shown how the metals in Class I., which are the bases of the alkalies, can be readily determined. If at the commencement of our operations we obtain a precipitate with carbonate of soda, we know that these three metals are excluded, and that we must look for the base amongst the remaining eight classes. In this case the precipitate gives no further indication, and we proceed to make a trial with the next reagent—liquid ammonia.

To a fresh portion of the solution we add the ammonia drop by drop. If we get no precipitate, we are sure that there is present one of the metals in Class II.—barium, strontium, or calcium. To determine which of these our salt contains, we adopt the following means : Add to the solution a few drops of *potassium chromate* (chromate of potash), and if a yellow precipitate is obtained the metal is *barium.* If there is no precipitate, take another portion of the concentrated solution and add calcium sulphate; this gives a precipitate, after a time, with *strontium*, whereas, if no precipitate appears, *calcium* is indicated. We can here again have recourse to that useful instrument, the blowpipe, to confirm the above indications. Make a little bead with the dry salt at the end of a platinum wire, moisten it with water, and heat in the reducing flame, as in Fig. 6. If a green colour is communicated to the flame, the metal present is barium.

If the flame burns with a crimson colour, strontium is present, whereas an orange or brick-red flame shows calcium.

We have thus disposed of Class II. ; but if we succeed in getting a precipitate with the liquid ammonia, we must proceed to test a fresh portion with caustic potash. The solution must be dropped

in by means of a pipette—a small piece of glass-ware in the centre of which is blown out an elongated bulb. This bulb is filled by sucking out the air from the

FIG. 4.—EXPOSING "BEAD" OF THE SALT TO THE OUTER OR OXIDISING FLAME.

If the flame turns yellow, the metal present is sodium; if violet, potassium is indicated.

top end, while the lower is immersed in the liquid. A pipette will deliver very small quantities at a time, according to the use of the finger in letting in the air. The caustic potash should be measured by it, as a slight excess of this reagent may dissolve the precipitate at first formed or prevent its formation altogether (Fig. 5). If we obtain a white precipitate with the caustic potash, we proceed to ascertain whether the precipitate is soluble or insoluble in excess of the reagent.

This action of potash is important, as it furnishes us with the means of distinguishing the metals in Class III. from those in Class IV. If the precipitate is insoluble, the metal must be sought for amongst those in Class III.; but if it dissolves or disappears, the metal is one of those in the next class.

The metals of the first of these classes are discriminated as follows: Add to the solution of the unknown salt some red prussiate of potash. If we get a brown precipitate, the metal is *manganese;* if blue, it is a *protosalt of iron;* if there is no precipitate, it is *magnesium.* The remaining two metals are distinguished from each other by sulphuretted hydrogen, which precipitates a yellow sulphide with *cadmium* and a brownish-black precipitate with *bismuth.* To confirm these results we again call in the aid of our blowpipe. Make a borax bead on the platinum wire, which is easily done by making the wire red-hot in the flame and dipping it into some powdered borax. Melt a little of the dry salt which we are analysing into this bead, and heat it in the outer or oxidising flame; the bead will acquire an amethyst tint—in fact, this action of manganese gives us a clue to the manufacture of artificial amethysts. Again, mix a few grains of the dry salt with an equal quantity of dry carbonate of soda, and put the mixture into a little hole scooped out in a piece of hard charcoal. Direct the point of the blowpipe flame upon it for a few seconds, and we get a kind of green glass. When we come

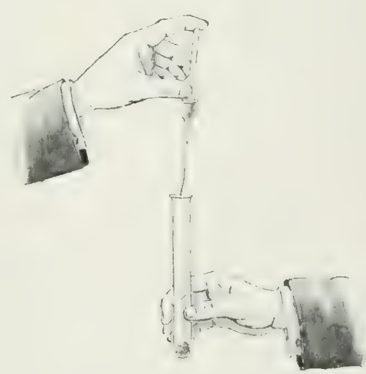

FIG. 5.—TESTING WITH CAUSTIC POTASH.

Note that the operator is using a "pipette."

to iron we may use as a confirming test *potassium ferricyanide.* This gives a white precipitate with protosalts of iron, which, however, rapidly turns blue, and a dark blue precipitate with persalts of iron.

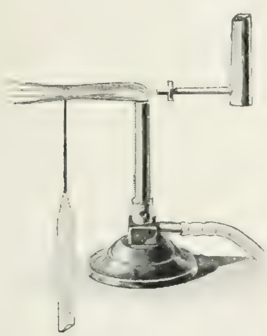

FIG. 6.—SHOWING THE INNER OR "REDUCING" FLAME.

If we find that the white precipitate obtained by caustic potash is redissolved by excess of that reagent, we proceed to test another portion of solution with *potassium ferricyanide*. A reddish-yellow or orange precipitate indicates *zinc*, and a dark blue-green precipitate shows a protosalt of *tin*. If, on the addition of ammonia, a white precipitate is produced which is insoluble in excess, this also indicates a protosalt of tin; the remaining four metals can be easily determined by sulphuretted hydrogen, which gives no precipitate with *aluminium*, a black one with *lead*, a yellow one with a persalt of *tin*, and an orange one with *antimony*. Salts of lead are well adapted to illustrate the action of the blowpipe. If a little of the salt is mixed with carbonate of soda or microcosmic salt as a flux, and heated upon charcoal (Fig. 7) in the inner or reducing flame, the metal will in a few seconds be reduced; that is to say, its affinity for the acid with which it was associated will be overcome, and it will appear on the charcoal as a bright metallic globule, which has the power of marking paper. The experiment may be repeated with similar results with a salt of tin or copper; but if the base is volatile, as in the case of mercury, a combustion-tube must be used, when the metal will be sublimed, or appear as an incrustation upon the side of the tube. The inner blowpipe flame only (Fig. 6) is adapted for the purpose of reduction, because here, as in the interior flame of a candle, the combustion is imperfect, and the heated carbon seizes upon the oxygen of the salt and releases the metal. In the outer flame the reverse effect takes place, for here the air has free access to the flame, and, being highly heated, is ready to part with its oxygen to any metal that may happen to be in the way. The experiment may be tried with a small fragment of lead, heated upon charcoal in the outer or oxidising flame. The temperature of this flame is sufficiently high to melt the lead, which does not liquefy below 600° F., and it will soon become converted into a greyish powder, and subsequently, by the absorption of more oxygen, into a yellowish mass composed of brilliant scales. This is the well-known *litharge* or *lead monoxide* (PbO) so much employed in the arts.

This litharge can readily be reduced or reconverted into a bead of metallic lead by heating it in the inner flame. The student should try his powers with the blowpipe on salts of tin, bismuth, and antimony.

The beads of these metals may be distinguished from those of lead by not being malleable or convertible into yellow oxides. Beads of bismuth are brittle, and those of antimony, when allowed to fall from the charcoal, divide into a number of smaller globules, which emit a thick white smoke of antimony oxide.

To return to our trial with caustic potash. If we get a black precipitate, the substance will be a protosalt of *mercury*; and blackish precipitate is sometimes obtained from gold, but the two may be distinguished by trial with *potassium ferricyanide*, which gives no precipitate with the latter, but a reddish-brown one with mercury. If our potash gives a blue precipitate instead of a black one, the base is one of the two in Class VI.—cobalt or copper. There will be no difficulty in distinguishing these from each other. If the solutions containing the blue oxides are boiled, the one which contains *cobalt* will turn *red*, while that which contains

copper will become black. A little of the dry salt of cobalt, about half the size of a pin's head, melted into a borax bead on the platinum wire, will give a beautiful dark-blue glass both in the outer and inner flames. Oxide of cobalt is thus used as a pigment for staining glass and porcelain. There are many confirming tests for copper, all of which are of an interesting character. The action of the blowpipe flame upon the salts of copper is instructive. Melt some of the salt into the borax bead and heat in the outer flame; a transparent green glass will be obtained. Try the experiment in the inner flame, and the result will be an opaque brown glass. In the first of these cases a hydrated oxide of copper, or the oxide in union with water, is formed, while in the latter the unconsumed carbon of the reducing flame, ever greedy of oxygen, causes the dehydration of the oxide, which then assumes its ordinary black colour. The salt may be reduced in the usual way upon charcoal (Fig. 7), when metallic copper will appear in the form of scales of the characteristic reddish-brown colour. A strong heat and a steady blast are required for this experiment, as copper will not melt below a temperature of 1,900° Fahr., and the student who has not acquired the practice of using the blowpipe without frequently leaving off to take breath, and thereby interrupting the blast, will not succeed in reducing salts of copper. A striking confirming test for copper is found in the addition of liquid ammonia to a solution of the salt. A splendid blue colour is the result, and this will be produced even when the salt is present only in small quantity. The deep blue liquid of the druggist's show bottles is produced in this way, being the ammonio-sulphate of copper, or copper sulphate and ammonia. Another equally characteristic test is the decomposition of the salt by iron. Make a strong solution of copper sulphate or nitrate, and dip into it a piece of polished iron or steel, as the blade of a knife. A coating of bright metallic copper will be immediately formed upon its surface, because the acid has a stronger affinity for the iron than it has for the copper, so that, instead of sulphate or nitrate of copper, we have in solution sulphate or nitrate of iron. This fact can easily be verified by the *potassium ferricyanide* test already described, which gives the reddish-brown precipitate of ferrocyanide of copper, which is soluble in caustic potash. Now, instead of a white, black, or blue precipitate with potash, suppose we obtain a green one; our metal will then be one of Class VII.—nickel, chromium, or iron protosalts and persalts mixed.

FIG. 7.—ASSAYING UPON CHARCOAL.

Turning to our *potassium ferricyanide*, if we get a dirty yellow precipitate, the metal is *nickel;* if no precipitate, it is

chromium; and if a light blue, it is *iron*. A little ammonia added to a salt of nickel gives a violet-coloured solution. Chromium, like copper, is interesting from the use of its oxide as a pigment for glass, porcelain, and other substances which have to be exposed to a high temperature. Oxide of chromium is green, and its property of staining glass may be demonstrated on a small scale by the borax bead and platinum wire. Melt into the bead a very small piece of the dry salt, and heat either in the inner or outer flame. In either case we shall get a transparent green glass. In this way a copper salt may be distinguished in the dry state from a chromium salt. The metals in Class VIII. give a yellow precipitate with caustic potash, that from gold being sometimes blackish. The potassium ferricyanide will give a reddish-yellow precipitate with *mercury*, but none with *gold*. There will, however, be no precipitate with mercury perchloride. This, however, may easily be distinguished by reduction in a glass tube with sodium carbonate or potassium cyanide, which is often a better flux, when metallic mercury in silvery globules will be sublimed, and may be caused to run together into a single globule.

We now come to the last class, which contains the two bases, iron (persalts) and silver. These yield a brown precipitate with potash. To distinguish one from the other we turn to our potassium ferricyanide, which gives no precipitate with *iron*, but a brown one with *silver*. The behaviour of silver salts with hydrochloric acid must here be noticed. If hydrochloric acid or solution of any chloride be added to a salt of silver, a white precipitate of silver chloride will be formed. This will be found to be soluble in ammonia, but insoluble in nitric acid. The dry salt may be reduced upon charcoal by the blowpipe, producing a bead of bright metallic silver. It has already been shown that salts of copper are decomposed by iron; soluble silver salts are in like manner decomposed by metallic copper. The experiment is an entertaining one, as under proper conditions the metal is deposited in an arborescent form, producing the well-known "silver tree." A good plan is to place a strong solution of silver nitrate in a wine-glass of such dimensions that it will support a copper coin about an inch or more from the bottom. The silver is deposited upon the under side of the coin, and ultimately hangs down like an inverted shrub.

We have thus discovered the base of the unknown salt, and the more difficult part of our task is completed.

The next business is the *examination for the acid*. For this purpose we must prepare standard solutions of the following four reagents—*barium nitrate, silver nitrate, lead nitrate*, and *calcium chloride*. Having made a concentrated solution of the salt to be analysed in the way already described, we test it with our first reagent —viz. barium nitrate. If we get no precipitate, the acid will be found in Class I.; that is to say, it will be either a nitrate, chlorate, chloride, iodide, arsenite, or sulphide. This being settled, we proceed to test another portion of solution with the nitrate of silver. If we get no precipitate, the salt is either a nitrate or a chlorate; if we obtain a white precipitate, it is a *chloride;* any other precipitate indicates one of the remaining three acids of the class. We have now to discriminate between nitrates and chlorates. Put a little of the dry salt into a large test-tube, and add hydrochloric acid. Hold the tube over the lamp or burner, and if the salt is a *nitrate* white fumes of nitric acid, which redden litmus paper, will be expelled. If the salt is a *chlorate*, a yellowish-green gas, having a very pungent odour, will be given off. A nitrate heated in the dry

state with dry bisulphate of potash gives off a dark yellow gas (nitrous acid). This effect is not produced with a chlorate. Both nitrates and chlorates give off oxygen when melted in a test-tube. A glowing match will burst into flame if plunged into the tube (Fig. 1). To distinguish between *iodides* and *arsenites* we must have recourse to the lead nitrate, which gives a yellow precipitate of iodide of lead with the former, and a white precipitate with the latter. *Sulphides* are readily tested by nitrate of silver, which yields a black precipitate of silver sulphide. A good confirming test for an iodide is bisulphate of potash. If some of this in the dry state is heated in a large test-tube with an equal quantity of the salt under examination, decomposition will take place, and the characteristic violet vapour of iodine will be observed. To confirm for arsenites, mix a very small quantity of the dry salt with carbonate of soda, and heat upon charcoal in the inner blowpipe flame. After a short ignition the odour of garlic will be perceived, by which the presence of metallic arsenic in the state of vapour is rendered evident. It need hardly be said that the student had better not linger over the poisonous fumes of arsenic longer than is necessary to recognise the characteristic odour. Sulphides may be detected by the smell of sulphuretted hydrogen gas, which is given off when they are heated with hydrochloric acid. The dry salt and the acid are put into a test-tube and slowly heated over a small flame. The odour of this gas is by no means so agreeable as that of arsenic vapour, being generally likened to that of rotten eggs, but it is equally unmistakable and characteristic. If we desire further confirmation as to its identity, we have only to allow the gas to impinge upon lead paper, or paper moistened with a solution of any lead salt, and the paper will turn black, owing to the production of lead sulphide. The acids in Class II. give a white precipitate with barium nitrate, which in each case is soluble in nitric acid without effervescence. If we get no precipitate with silver nitrate, the acid is a *fluoride*; if a yellow, it is a *phosphate*; and if a brown or chocolate colour, it is an *arseniate*. The borates and oxalates are distinguished by calcium chloride, which, with the *borate*, gives a white precipitate which dissolves on adding more water, and with an *oxalate* a white precipitate insoluble in water. To confirm for fluorides mix some of the dry salt with bisulphate of potash in a test-tube, and apply heat. Hydrofluoric acid gas, which has the property of corroding glass, will be disengaged. The corrosion on the glass will be best observed after washing and drying the tube.

A very interesting experiment showing the action of hydrofluoric acid on glass may be performed by adding strong sulphuric acid to powdered fluor-spar, when hydrofluoric acid is liberated. Coat a watch-glass with paraffin wax and then write on it with a needle, thus scratching away the wax from certain portions. This glass should then be placed over the vessel in which the hydrofluoric acid is being generated. In time the acid eats into the glass, and etches on it whatever has been written. The action is accelerated by heating. The most delicate test for phosphoric acid is *molybdate of ammonia*. To the solution to be tested add some of the ammonium molybdate, and then a few drops of nitric acid, and boil. A yellow precipitate will be obtained if phosphate is present.

No other acid than a phosphate will yield this precipitate with an acidified solution of molybdate of ammonia. The oxalates are interesting from the decomposition which they suffer when heated. The operation is performed in a test-tube over a moderate heat; effervescence takes

place, and a gas is given off which is a mixture of carbon monoxide and carbonic dioxide, or carbonic acid gas. On applying a light to the mouth of the tube the former burns with a blue flame, notwithstanding its dilution by the incombustible carbon dioxide. If some of the oxalate be heated with strong sulphuric acid, carbon monoxide is evolved, and on applying a light it burns with a blue flame. When carbon monoxide burns it takes up oxygen and becomes converted into carbon dioxide. This simple change occurs when an ordinary fire burns, the light blue flame noticeable on the top of the coals being the carbon monoxide burning to the dioxide. The equation which expresses the change which takes place is

$$\underset{\text{(Carbon monoxide)}}{2CO} + \underset{\text{(Oxygen)}}{O_2} = \underset{\text{(Carbon dioxide).}}{2CO_2}$$

From a soluble borate we can obtain boracic acid, which tinges the flame of alcohol a beautiful green. To obtain the acid in crystals boil a concentrated solution of a borate with sulphuric acid, and let the mixture cool. The boracic acid will appear at the bottom of the test-tube or evaporating dish, in which the operation may be conducted, in the form of flat, shining crystals. These should be collected on a filter, and repeatedly washed with water to remove all traces of sulphuric acid, and kept for subsequent experiments. To observe the green flame, dissolve some of the crystals in alcohol or methylated spirit in a saucer, and ignite the mixture, stirring occasionally with a glass stirrer.

Class III. contains only the carbonates, which also give a white precipitate with barium nitrate, but are distinguished from those in Class II. by dissolving in acids, with effervescence, owing to the escape of carbonic acid gas. This gas may be recognised by passing it into a solution of lime-water, which it turns milky by reason of the formation of carbonate of lime, which is insoluble in water and becomes precipitated. This milkiness of lime-water may be obtained by blowing air from the lungs into the water. The reaction which takes place is as follows :—

$$\underset{\text{(Carbon dioxide)}}{CO_2} + \underset{\text{(Lime-water)}}{CaH_2O_2} = \underset{\text{(Carbonate of lime)}}{CaCO_3} + \underset{\text{(Water)}}{H_2O}$$

The action of acids on carbonates is readily seen when pouring acid on chalk, effervescence and escape of CO_2 being very active.

$$\underset{\text{(Calcium carbonate)}}{CaCO_3} + \underset{\text{(Hydrochloric acid)}}{2HCl} = \underset{\text{(Calcium chloride)}}{CaCl_2} + \underset{\text{Water}}{H_2O} + \underset{\text{(Carbon dioxide)}}{CO_2}$$

The gas, if passed into lime-water again, goes to form the carbonate from which it originates.

The *sulphate* in Class IV. also gives a white precipitate with nitrate of barium, but it is quite insoluble in acids. A sulphate may be further identified by the following process. Mix some of the sulphate with dry carbonate of soda, and heat on charcoal in the inner blowpipe flame. After a few seconds' ignition remove the fused mass and place it upon a piece of bright silver. In a short time a black mark will be observed on the metal, owing to the production of silver sulphide. Or if some hydrochloric acid is added to the fused residue, sulphuretted hydrogen will be given off.

We shall have no difficulty in distinguishing *chromates*, as they are the only salts on our list which give a yellow precipitate with barium nitrate. Chromates may also be recognised by the fact that they turn green and give off chlorine gas when heated with hydrochloric acid. If heated with strong sulphuric acid, a green coloration is also produced, but oxygen is given off in place of chlorine.

If the substance presented for analysis prove to be insoluble, it must be examined by the blowpipe, both upon charcoal and in the borax bead, and in other ways it is impossible to discuss here. Its

insolubility is ascertained by evaporating a little of the water in which we have attempted to dissolve it. There should be no residue. As we have thus discovered both the base and the acid of the unknown soluble salt, our task is completed.

Experience has proved that the analytical course here presented to the reader, though necessarily brief, is sufficiently copious and explicit for elementary practical work, and that the young student, with the scheme before him, will be able after a week's good practice to analyse any simple salt, provided that it is pure and does not contain any other acid or base than those which appear on our list. He must set about his work, however, in a methodical manner. Pen, ink, and paper are essential adjuncts to his apparatus. The colour and character of every precipitate, and with what reagent produced, must be jotted down in their appropriate columns; the metal or acid indicated by these precipitates, and the class to which it belongs, must then be prominently recorded, together with the blowpipe and other tests used to confirm the results already arrived at. The analysis of compound substances and mixtures composed of several salts is a much more complicated task, the practice of which the student will do well to defer till he has thoroughly mastered the scheme here presented to him.

FIG. 8.—WARMING PRECIPITATE IN A TEST TUBE.

A GROUP OF CARNIVOROUS PLANTS.

1. PITCHER PLANT (*NEPENTHES*). 2. SIDE-SADDLE PLANT (*SARRACENIA*). 3. SUNDEW (*DROSERA*). 4. [illegible] FLY TRAP (*DIONÆA*). 5. BLADDERWORT (*UTRICULARIA*). 6. *DARLINGTONIA*.

CARNIVOROUS PLANTS.

By ALEXANDER S. GALT.

WE already know something of the way in which plants obtain their food and of what that food consists.* We know that plants are, as a rule, content to take in, through the medium of their roots, certain simple salts which are soluble in water, and from them obtain nine of the ten elements which they must have in order to make healthy growth; also that the remaining element—carbon—is obtained from the carbonic acid gas in the air through the instrumentality of the leaves. Thus far goes the rule; now we have to deal with some of the exceptions, and in this paper we have to consider the rather important section of them grouped under the title of *carnivorous plants*.

There are in all five hundred or thereabouts of these flesh-eating members of the vegetable kingdom. Why they have renounced the habits of their kind, or, rather, why they have added to the ordinary functions of the plant this taste for flesh—for it must be distinctly understood that even with carnivorous plants both leaves and roots perform the normal as well as the abnormal functions—is, perhaps, rather difficult to exactly determine. On the other hand, it is not difficult to find a probable reason. The all-important nitrogen, so necessary to the formation of protoplasm, must be obtained somewhere and somehow. The pod-bearers (*Leguminosæ*) have hit upon one way; the flesh-eating plants have found out another. All these carnivorous plants grow wild in positions that are almost invariably poorly supplied with nitrogen—nitrogenous salts, that is. Some cling to the rocky, inhospitable sides of mountains, where the little earth obtainable is ensconced in chinks amongst the rocks; others, as in the case of the *Nepenthes* (Fig. 1), have planted themselves upon the stems and branches of tall trees, where earth is equally at a premium; some, as with our pretty little native sundew, are to be found only in boggy places; and others, like the bladderworts (*Utricularia*), have gone a step further than this and are to be found only in pools of stagnant water. Unlike as these several positions are on the whole, in one respect at least they resemble each other—there is in each case a lack of the nitrogenous salts without which the vegetable cannot live. It may be, therefore, that in seeking to make good this deficiency the carnivorous subject turns to organic bodies, such as insects and animalculæ, as the readiest source of supply. We know, at any rate, that the nitrogen thus obtained is beneficial to the plant. Whether it is also essential is another phase of the subject that we can scarcely argue upon. It has been advanced that the sundew, for instance, and the *Pinguicula*, may be cultivated and isolated from insects with conspicuous success; but this only proves that the essential nitrogen has been supplied by the cultivator, so that the plant is not compelled to continue its carnivorous habits. That it does continue them if it has the opportunity is a well-known fact, but the continuance is probably due to the pertinacity of old habits.

A peculiar interest attaches to the doings of these animal-eating plants, and many a romancer has given full rein to his imagination in conjuring up for the benefit of readers some impossible sort

* "How Plants Feed," CASSELL'S POPULAR SCIENCE, Vol. I., p. 280.

of flesh-eating vegetable monster whose doings he loves to recount. Fortunately, perhaps, Nature knows of no organism upon quite such a large scale. She has not yet produced plants which are capable of ensnaring and feeding upon man and the higher animals. But eliminate the question of size, and we shall find that the novelist has not gone so far astray in his delineation of the methods of these abnormal vegetables. The devices which they adopt to enable them to secure their prey are almost innumerable, and some of them are ingenious. Picture the bladderwort (Fig. 2), with its countless bladders borne upon the waving branches, the latter spreading hither and thither in the gloomy recesses of the stagnant pool—so many death traps waiting for the poor, heedless animalcule which ventures within reach of its doom. Or take the tentacles of the sundew, outspread, waiting for the unwary fly to rest for a moment upon the brightly tinted spoon-shaped leaves; or, again, the artfully contrived "pitchers" of *Nepenthes* and *Sarracenia*, bright hued to catch the eye of the inquisitive insect, lined with honey to tickle its palate, slippery with wax to prevent its struggling footsteps from staying its fall to the precipitous depths below, where certain death awaits it. Take, again, the sticky snare of the showy flowers of the pretty *Pinguicula* or butterwort; herein, too, lurks a trap for the unwary visitor who takes too much for granted.

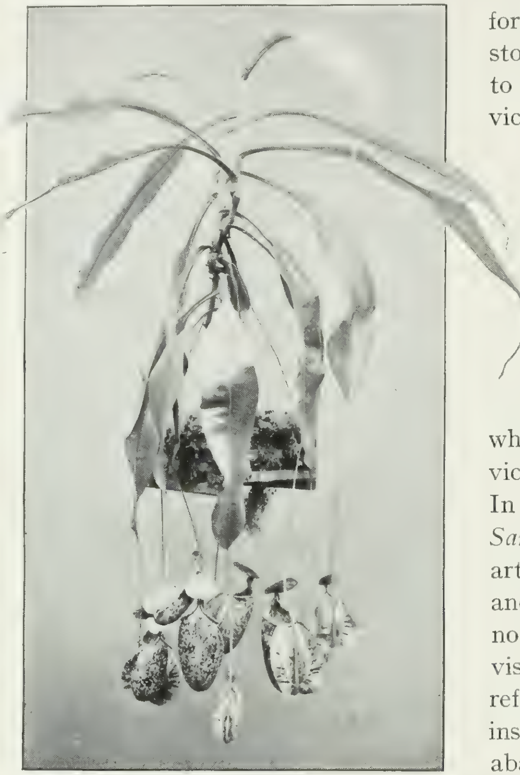

Photo: Cassell & Co., Ltd.
FIG. 1.—ONE OF THE PITCHER PLANTS (*NEPENTHES AMESIANA*.)
The pitchers are formed from much modified leaves.

In all these instances, although the actual trap may be differently contrived, there is marvellous subtlety displayed. The victim does not know of its danger until it is too late to escape. Patiently the snarer has waited for its prey; just as stolidly does it refuse to let that luckless victim go, once it is in the toils. In this latter direction alone considerable diversity of device is displayed. Perhaps the simplest is the tenacious liquid which glues the victim to the snare. In *Nepenthes* and *Sarracenia* we have artfully placed spines and hairs, which offer no resistance to the visitor, but resolutely refuse egress. The inscription "All hope abandon ye who enter here" might well be written above the gaily painted pitcher of *Nepenthes* and *Sarracenia*.

All these so-called flesh-eating plants belong to one of three main groups:—

(1) Plants which have pitfalls to catch their prey. Familiar examples are to be found in *Nepenthes, Sarracenia, and Utricularia*.

(2) Plants which exhibit movements in order to catch their victim. These movements take place as the result of a stimulus imparted by contact with the insect, and one of the results is that the latter is covered by an excretion of digestive fluid.

A good example is to be found in the Sundew (*Drosera*).

(3) Plants which exude liquid gum and catch their prey by gumming him to themselves, the said gum being strong enough to hold the victim securely until all the vital juices have been sucked from his body, and there is nothing left but the empty shell. Neither are pitfalls to be found in this group, nor are there any apparent movements to be observed in response to stimuli. The various members of the genus *Pinguicula*, which are Alpine plants, with pretty flowers, are excellent instances of this division.

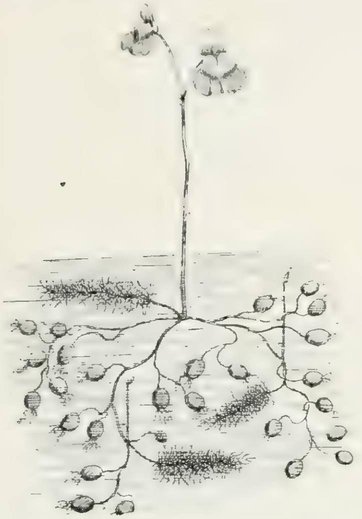

FIG. 2.—A BLADDERWORT (*UTRICULARIA GRAFIANA*.)
(*After Kerner.*)
The bladderworts are nearly all aquatics, and are usually to be found in stagnant ponds and ditches. Each plant carries a great number of these submerged bladders, which are really traps for insects and animalculæ.

We will take a few of the most important representatives of each group or section, and observe, as far as space will permit, how the work is done.

Amongst those subjects which catch their prey by means of traps or pitfalls, the bladderworts (*Utricularia*) (Fig. 2) occupy a prominent position. For the most part, the bladderworts are aquatics, but a few species, of which the Brazilian *U. montana* is an example, grow in the bark fissures of big trees or in chinks in the rocks. The aquatic *Utricularias* consist of a network of rootless branches, carrying great numbers of the "bladders." These branches are spread out just beneath the surface of the water during the season of active growth, but sink to the bottom as winter approaches. The greater part of the stems and branches die when the cold weather comes, but succession is secured by means of "*winter buds*," which are formed at the tips of the branches. The leaves are thread-like, and the "bladders" pale green and more or less transparent.

The mechanism of the "bladders" is highly interesting. There is a contrivance at the opening which may be likened to a pair of lips, one of which is much thicker than the other. Attached to the upper of these lips is a thin "valve," working against a "cushion" formed by the lower "lip." This valve may be easily pushed in so as to allow a tiny organism to enter; but, being elastic, it closes up behind the visitor, who is quite unable to force it *outward* and thus secure

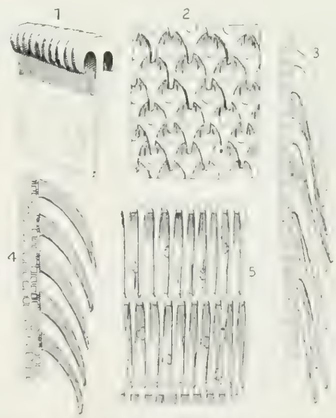

FIG. 3.—SPINES IN THE PITCHERS OF CARNIVOROUS PLANTS.
(*After Kerner.*)
These spines point downward in such a way that, whilst offering no obstruction to visitors entering, they prevent egress.
1. Lining of rim of pitcher in Sarracenia.
2. Spines in Heliamphora.
3. Spines at bottom of pitcher in Sarracenia.
4. Part of the tube of Genlisea.
5. Spines fringing the inside of the pitcher of Nepenthes.

escape. The relatively stiff, bristle-like hairs that fringe the mouth of the "bladder" also hinder egress. No matter what attempts the animal makes to get free, it cannot get out; death ensues, either from suffocation or starvation, usually in from twenty-four to thirty hours, although some specially vigorous prisoners will live for several days. The products of the decomposition of the bodies are taken in by a series of absorption cells, which line the whole interior surface of the "bladder." The absorption cells lie in fours, and are arranged in cruciform fashion. The British species are *U. vulgaris*, *U. minor*, and *U. intermedia*.

Photo: Cassell & Co., Ltd.

FIG. 4.—*CEPHALOTUS FOLLICULARIS*, A CURIOUS PITCHER PLANT FROM EASTERN AUSTRALIA.
This plant is only a few inches high, and the brightly hued pitchers catch many wingless, creeping creatures.

Passing now to the *Nepenthes*, we find plants whose leaves have been metamorphosed into imposing-looking pitchers, which are often gaudily coloured and highly ornamental. The pitcher proper is formed by the leaf-stem or *petiole*, and the lid at the top forms the remains of the leaf blade. The pitchers are pendant, as shown in Fig. 1 and in the Coloured Plate. In *Nepenthes* we must take note of three distinct portions of the mechanism, all of which help forward the end in view. First, we have the means of allurement, as furnished by the gaudy coloured pitcher; also the secretion of nectar under the lid and about the rim of the pitcher. Then comes in the trap proper, which is a pitfall from which egress is barred by means of sharp, spine-like hairs pointing downward. Finally there is the secretion of digestive fluid by means of special cells at the bottom. The liquid with which the pitcher is usually nearly filled probably also finds its source in the plant; it serves to effect the speedy dissolution of the victims by drowning, and at the same time dilutes the digestive fluid previously mentioned.

The novelist has now and again endeavoured to save the life of a hero or heroine dying from thirst by making him or her drink of this uninviting fluid, but when we come to consider the condition the liquid is in—full of dead and decaying insects, with perhaps more than one fat maggot—we can believe that its effect upon exhausted humanity would not be exactly that of an elixir. Speaking of these self-same maggots, there are some very enterprising birds belonging to the

Malay Archipelago—which, by the way, is the headquarters of the *Nepenthes*—which slit the pitchers with their sharp bills and extract the maggots for their

FIG. 5.—ONE OF THE BUTTERWORTS (*PINGUICULA CAUDATA*).

own benefit. Referring once more to the fluid contents of the pitcher, opinion as to its digestive powers has see-sawed to and fro a good deal, but it is now held that it has digestive properties. Not only does its chemical composition bear a close resemblance to that of the gastric juice of animals, but it has the power of dissolving albuminous substances in precisely the same fashion.

The side-saddle plants (*Sarracenias*) (Coloured Plate) and the *Darlingtonias* act in much the same way as the *Nepenthes*. There are the allurements of bright coloration and of nectar; the slippery pitfall, guarded above, but in this case by scales similar to those found upon a pike's back; and death by drowning at the bottom. The liquid, after acting upon the bodies of a few insects, turns dark brown in colour, and has a most unpleasant smell. It is fortunate that the novelist has never attempted to make his heroine drink from the pitchers of the *Sarracenia*.

Cephalotus follicularis (Fig. 4), an eccentric relative of the *Saxifrages*, is a native of Eastern Australia. Its leaves are produced rosette fashion round the stalk, but only the lower ones take upon themselves the task of forming traps. The allurements of bright colours and nectar, found so effective in *Nepenthes* and *Sarracenia*, are copied by the *Cephalotus*, as is also the bath of acid fluid at the bottom. This liquid does not turn putrid, as we have noticed is the case in *Sarracenia*.

Coming now to the second group, in which we find plants making a set of movements to assist in capturing their prey, there are many highly ingenious contrivances. We remember that the stimulus of an insect in contact is sufficient to set what we might not inaptly call the machinery in motion. Sometimes we get so sudden a closure of the tentacles that the visitor is surprised, and has no time to escape; or, again, the mechanism may be slow in its movement, and sticky fluid is exuded to give it time to act, as with the sundew. The butterworts, of which one species is shown at Fig. 5, belong to this section. There are about forty species, of which three (*Pinguicula vulgaris*, *P. alpina*, and *P. lusitanica*) are British. All are sub-aquatics. A transverse section of a *Pinguicula* leaf, at Fig. 6, gives some idea of the shape of the

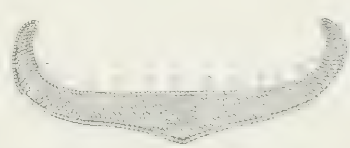

FIG. 6.—*PINGUICULA* LEAF IN TRANSVERSE SECTION.

Note the glandular hairs, which exude an adhesive fluid.

glandular hairs which excrete the adhesive fluid, but it gives no inkling of their minuteness and their number. According to calculations which have been made, there are 25,000 of these glandular hairs upon a square centimetre of a leaf, so that

a small plant is carrying several hundreds of thousands of these little outgrowths. These tentacular hairs are sensitive to the continuous contact of an organic body; pressure from any foreign body will stimulate them to some extent, but only in the case of organic bodies is an excretion of digestive fluid the result. This power of discrimination in so tiny an object as one of these glandular hairs is sufficiently remarkable. Small insects are fixed firmly

FIG. 7.—ROUND-LEAVED SUNDEW (*DROSERA ROTUNDIFOLIA*).

The leaves are bright rose pink, much smaller than a threepenny piece, and are covered with relatively large, blob-pointed hairs.

by the gluey mucilage, then the acid secretion is poured out from the glands, and the butterwort proceeds to digest its victim at its leisure. Grains of pollen brought by the wind to the leaves share the same fate, only in this case there are no frantic struggles for freedom.

Without going into detail, we may state at once that there is very little difference between digestion as carried on in the stomach of an animal and this process of absorption from the body of a captured insect on the part of the butterwort. The acid secretion from the butterwort leaf will produce precisely the same effect upon animal milk as rennet, and its antiseptic properties are turned to account by Alpine shepherds for the curing of sores upon the udders of their cows, as is well known.

It will be gathered that the mechanism of the butterwort leaf is not speedy in its action; in this respect it is different from the behaviour of the sundew (*Drosera*). This pretty little plant is quite a common tenant of marshy moors, and is generally found in company with sphagnum moss. Fig. 7 shows something of the general characteristics of *D. rotundifolia*, the commonest of the three British species. There are many other species which are not found in the United Kingdom. Although the leaves are very small, the tentacles are relatively large, and their mechanism can be easily seen. A glance at Fig. 8 will assist, and then we may turn to Fig. 9, where the hapless insect is shown fixed in the remorseless clutches of the tentacles. As the round-leaved *Drosera* easily accommodates itself to cultivation, the student of nature may provide for himself much amusement and food for thought by obtaining a few plants, placing them in a cool greenhouse, and watching their behaviour. Experiment soon decides several things :—

(1) That light but continual pressure of other leaves against the plant does not affect the delicate mechanism of the tentacles.

(2) That if a foreign inorganic body, such as a small pebble, be placed upon the blade of a leaf, the tentacles after a time close upon it, but do not remain long closed. It seems that they have the power of discovering that the object is not good for food, and having found that out they unclasp and spread themselves out as before. This may be made the subject of a very pretty little experiment.

(3) Contact with an organic body brings about three things :—(*a*) The tentacles

close over it as they do with the pebble; (*b*) a flow of mucilage follows; and (*c*) there is secretion of acid fluid that possesses digestive properties.

Acidity may be demonstrated by the usual chemical test—the turning of blue litmus red. Amongst smaller details we shall almost certainly find that the longest tentacles upon the leaf margin are the most active, and appear to give the lead to their shorter and centrally situated fellows. If only one piece of meat or one insect is the prize, all the hairs will converge towards one point; if two pieces of meat or two insects are in question, the tentacles split up into two camps, as it were. As long as nutriment can be absorbed from the substance thus enclosed, so long do the tentacles maintain their grip—a small fly will keep them fully occupied for a couple of days; then the tentacles straighten out, the empty shell of the

a *b*

FIG. 8.—SHOWING THE STRUCTURE OF A TENTACLE OF THE SUNDEW.

(*After Morren.*)

a. External view. *b. Internal view.*

insect is rejected, and the leaf is ready for another victim.

Some interesting experiments have been made with a view to demonstrating the degree of sensitiveness of which the glandular hairs of the sundew are possessed. There is no result more striking than that in which a piece of human hair only ·2 millimetres long and weighing

FIG. 9.—TENTACLE OF SUNDEW GRASPING AN INSECT.

·000822 milligrammes was found sufficient to cause movement of the tentacle touched.

There are several other genera of insectivorous plants belonging to the natural order to which the *Drosera* is assigned (*Droseraceæ*); the chief of them are *Dionæa*, *Aldrovandia*, *Roridula*, *Byblis*, and *Drosophyllum*. Of these Venus's flytrap (*Dionæa muscipula*) is the most interesting. An illustration of it will be found in the Coloured Plate. The plant is a native of a strip of boggy ground in eastern North America. The leaves display an arrangement that can, perhaps, best be likened to an ordinary steel gin with very long and sharp teeth. If excited, the two lobes of the leaf close up—from ten to twenty-five seconds being the time occupied in doing this—and the sharp teeth interlock. If the body imprisoned is organic the glands begin to secrete the colourless but slimy digestive fluid, and the leaf remains closed until the work of digestion and absorption is complete. From eight to fifteen days is

generally needed to complete this operation, although with comparatively large objects several more days are required.

In the third group, where are placed the plants with adhesive apparatus simply, we are chiefly concerned with the fly-catcher (*Drosophyllum lusitanicum*), a native of Portugal and Morocco (Fig. 10). The quantity of mucilage and digestive fluid exuded by the fly-catcher is, relatively to other flesh-eating plants, very great, and the name "fly-catcher" is the direct result of this. The peasants in parts of Portugal use the plants in much the same way as we use fly-papers, and they are said to be quite as effective.

There are many other insectivorous plants which might claim attention, but we have looked at a few of the most important, and from them have gleaned some idea of the vast amount of resource which has been exhibited in the making of the various snares and pitfalls used. As was pointed out in the beginning of the paper, the plants have probably taken to a flesh diet with a view to make good Nature's deficiencies in the soil, but at the same time there is no gainsaying the fact that cultivated plants which have not this excuse for the flesh-eating habit continue to indulge in it whenever the opportunity occurs. It is an interesting and instructive chapter in Nature's book of morals.

FIG. 10.—*DROSOPHYLLUM LUSITANICUM*, THE FLYCATCHER.
(After Kerner.
This curious plant is used by the natives of Portugal as a substitute for flypapers

A PAGE FROM THE STORY OF THE PAST: FLYING REPTILES.

OF all the powers possessed by one or other of the varied tribes of animals. there is none which has been more universally alike the admiration and the envy of the human race than that of flight. The philosopher has investigated the mechanism by which the bird or the insect is able to raise itself above the ground; and the capacity for traversing swiftly the vast and wandering fields of air has formed the theme of many a poet, while even the most commonplace of mankind is fain to gaze in wonder as he sees the hawk sailing in graceful circles, with wide-extended pinions, o'er his head, or as he watches the rapid evolutions of the untiring swallow. Or yet again, if he be a traveller and has visited the South American Andes. he must have marvelled at the condors, with their huge, outstretched, and apparently motionless wings, sweeping round in vast circles high above him, to all appearance with no exertion whatever. At the present day, the only animals which are endowed with the marvellous power of aërial locomotion, or of "flight" properly so-called, are the birds, the insects, and the bats; some of the two former members of these groups being, however, unable to support themselves in the air. Speaking generally, therefore, these three groups of animals are the only ones which possess the power of "flight"; but the object of this paper is to show that there formerly existed animals belonging to a different class—namely, to the class of the Reptiles—which were likewise capable of flying; and in pursuit of this object we must explore the recesses of the past, and carefully examine some of the bones which geologists have exhumed from what are called the "Secondary Rocks."

While we have this definite object in view, and while we must leave for the present the discussion of the laws and conditions under which flight is carried on, it is, nevertheless, necessary that we should just consider for a moment what we mean by the term "flight," for a great deal turns upon our accurately understanding this. Now, in the strict sense of the term, the power of flight is limited to the power of raising the body above the surface of the earth, of supporting it in the air, and of transporting it from place to place in the atmosphere. Accepting this definition, the only animals which now possess the power of "flight," as before said. are the birds. the insects. and the bats; and all of these fly by means of organs which are technically and popularly called "wings." These wings are organs which are differently constructed in each of the three groups of animals just mentioned, but which, in each case, are instruments adapted for beating the air by successive strokes, and moved by special muscles. All animals, then, which fly have "wings," in the above wide sense of the word. There are, however, many animals now existing which are often spoken of as "flying" animals, though, in truth, they possess no power of "flight." The animals, for example, which are called "flying squirrels," the little "flying phalangers" of Australia (Fig. 1), and the "flying lemurs" of the Indian Archipelago, come under this head. They all possess more or less extensively developed folds of skin, which spring from the sides of the body and are attached to the fore and hind legs. By stretching out the legs these lateral membranes are extended, and are thus rendered capable

of acting as a support in the air, fulfilling precisely the same function as the "parachute" of the aëronaut. It is clear, however, that we have to deal here with structures very different from true "wings," and with a function not comparable with true "flight." The animals we have just alluded to have no power of raising their bodies from the ground by means of their "flying-membranes," nor can they beat the air with successive strokes of these organs. All that they can do is to raise themselves to a certain height by climbing and then launch themselves out into the air from the elevation thus attained to some lower point. In this procedure, the widely extended lateral membranes serve to render their descent towards the earth a gradual and slowly progressive one, and they are thus enabled to execute very prolonged and extensive leaps from tree to tree. Thus the North American Flying Squirrel (*Sciuropterus volucella*) can take leaps of 20 yards, and the Flying Lemur (*Galeopithecus volans*) (Fig, 9) can negotiate upon occasion from 50 to 70 yards. It will be evident, however, that in no proper sense whatever can these animals be said to "fly."

FIG. 1.—FLYING PHALANGER (*PETAURUS*).
These "Flying Squirrels," or "Sugar Squirrels" as they are called in Australia, feed upon fruits, flowers, and insects.

Nor is it only among the quadrupeds that we find this power of darting through the air by means of lateral expansions. Thus, in the so-called "flying-fishes," the animal is able to dart out of its natural element into the less substantial air, and to perform leaps of great length, by means of the front pair of fins, which are of immense size, and which act exactly like the lateral folds of skin in the "flying squirrels." A still more singular example, and one bearing more directly on the subject now before us, is to be found in the extraordinary little lizards which are known as "flying dragons" (Fig. 2), and which are found in the forests of India and the Indian Archipelago. In these wonderful reptiles we have animals essentially similar to our ordinary lizards, but having the sides of the body furnished with wide folds of skin. These folds are supported by the hinder ribs, which run out straight from the back-bone, and which can be made to expand the "flying-membranes" in much the same way as the ribs of an umbrella enable us to open it. As in the case of the "flying squirrels," however, the "flying dragons" have no power of true "flight." They climb among the trees, and, having reached a suitable elevation, they dart down upon the insects upon which they live, their so-called "wings" simply allowing them to accomplish leaps of comparatively enormous length without injury to themselves.

At the present day no known reptile possesses the power of true flight; but geology teaches us that there existed in past time a large number of most remarkable reptiles which could "fly" in as

genuine a sense as the birds and the bats among existing animals. In other words, they possessed organs which may fairly be called "wings," since they could be made by appropriate muscles to beat the air with successive strokes, to support the body of their proprietor in the air, and transport it from place to place. The reptiles to which we refer are all extinct, not having even a near relation now in existence; and for reasons which we shall afterwards understand, they are known by the general name of "Pterodactyles." They are found in association with a very large number of other extraordinary types of reptiles, imbedded in the rocks which geologists call the "Secondary Rocks," so that they belong to what we may consider as the middle period of the earth's history. Though mostly found in a fragmentary condition—a skull in one place, an arm in another, and a leg in a third—we have, nevertheless, been able now to satisfactorily piece together the detached relics of these ancient reptiles, and it is worth our while to consider briefly their organisation and structure.

The ordinary forms of Pterodactyles (Fig. 3), as found in the fine-grained lithographic slates of Solenhofen, in Bavaria, or in the blue shales of the "Lias," at Lyme Regis, are comparatively small animals, mostly about the size of a pigeon or a raven. In the chalk, however, as we shall subsequently see, occur remains of gigantic members of this group, the dimensions of which greatly exceed those of the largest of living birds. Commencing with the head, we find the skull to be singularly bird-like in its general form, and to be so constructed as to combine to a wonderful extent great strength along with the utmost lightness and economy of material. The jaws are long and beak-like, and would remind one very strongly of the bill of a bird, were it not for the fact that they are provided, throughout or over a portion of their length, with sharp conical teeth, sunk in distinct sockets. In the presence and characters of the teeth the Pterodactyles resemble the crocodiles and alligators among the reptiles, and differ from all living birds, though a few fossil birds are also provided with teeth. There is also the curious fact that the huge Pterodactyles which are found in the chalk had no teeth at all, the jaws being apparently sheathed in horn, thus resembling the beak of a bird. As some fossil birds, therefore, possess teeth, and as some Pterodactyles were toothless, it is evident that we cannot use the characters of the jaws as separating the two groups. The only other point about the skull which need be noticed here is that the "orbits"—that is to say, the bony chambers in which the eyes were lodged—are of comparatively enormous size. From this it may be safely inferred that the Pterodactyles possessed greatly developed organs of vision; and a strong probability is thus established that they were nocturnal animals, like our living bats, sleeping all day, and coming out in the twilight in search of food.

FIG. 2.—A FLYING DRAGON (*DRACO*).
(*Natural size.*)

These curious little lizards are found in the forests of India and the Indian Archipelago. The "wings" shown at the sides of the body are really wide folds of skin.

If we look to the characters of the back-bone in the Pterodactyles, we find

that these curious animals present some features which would ally them with the birds, and others in which they approach the reptiles. Thus, the neck is long and slender, closely resembling that of a bird, while there is in some cases a long and slender tail, such as we find in no living bird, though we are familiar with such a structure in a large number of existing

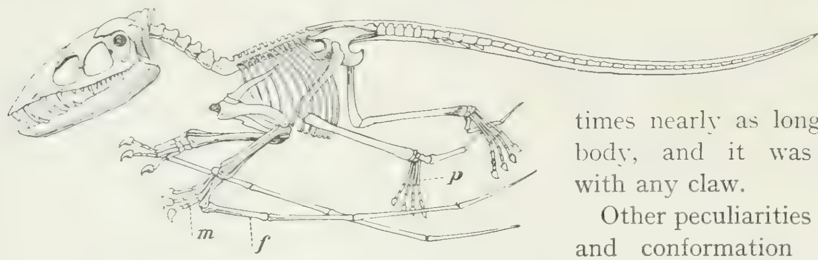

FIG. 3.—SKELETON OF A PTERODACTYL (*DIMORPHODON MACRONYX*).

m, hand; f, greatly elongated little finger carrying the flying-membrane; p, foot.

reptiles. While the tail is often long (*see* Fig. 3), other Pterodactyles, however, had a quite rudimentary caudal appendage.

But it is in the structure of the limbs, and especially of the fore-limbs or arms, that the Pterodactyles show their most extraordinary peculiarities. The hind-legs of the Pterodactyles, though sometimes very feeble, are generally well developed, and are clearly suited for walking upon the ground, as well as for enabling their possessor to climb actively among the trees. Four of the toes carry sharp claws, which the animal doubtless used in grasping. The fifth toe, corresponding with our "little toe," was either rudimentary, or in other cases was longer than the other toes, and was employed in stretching and extending the "flying-membrane" which we shall afterwards see these animals to have possessed. The fore-limb or arm of the Pterodactyles consists essentially of the same bones as we should find in the fore-leg of a dog, or in the arm of a man; but there is a most marvellous modification of the structure of the hand (*see* Fig. 3, *m*). There are only four fingers to the hand, the "little finger" being apparently wholly wanting. The thumb, the forefinger, and the middle exhibit no special peculiarities, being of a size proportionate to the dimensions of the animal itself, and furnished with sharp claws. The fourth finger, on the other hand, corresponding with our "ring-finger" (Fig. 3, *f*), is of immense length, sometimes nearly as long as the whole body, and it was not furnished with any claw.

Other peculiarities in the structure and conformation of the Pterodactyles will appear as we proceed; but we may now inquire how far the data above given enable us to judge as to the habits and probable mode of life of these singular reptiles. We have seen, then, in the first place, that the feet are adapted for walking on the ground, or for climbing among trees; but we are forced at once to conclude that the animal could not possibly have walked on all-fours, as the enormously elongated ring-finger would clearly render this mode of progression an impossibility. It is clear, therefore, that in walking on the ground the Pterodactyles must have been as genuine bipeds as birds; and the entire characters of the skeleton prove that this view is the correct one,

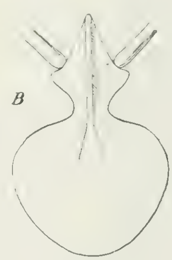

FIG. 4.—BREAST-BONE OF A PTERODACTYL.

and that the hind-limbs alone were used in supporting the weight of the body. To what use, then, did the animal put its wonderfully constructed hands? In the reply to this question we have a very beautiful instance of the mode in which the naturalist is enabled to reason with

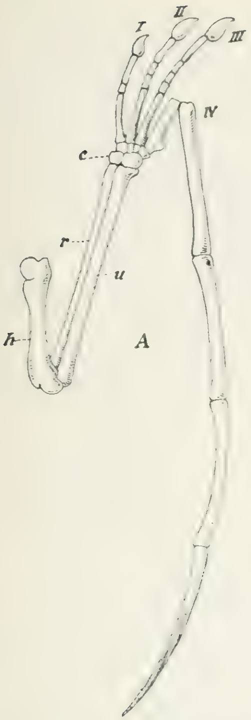

FIG. 5.—ARM AND HAND OF A PTERODACTYL (*PTERODACTYLUS CRASSIROSTRIS*).

h, *bone of upper arm*: *r* and *u*, *bones of fore-arm*: *c*, *bones of wrist*: *I*, *thumb*: *II*, *III*, *IV*, *fingers*.

certainty as to the unknown from what he already knows, and to re-construct the strange creatures of the past by observations made on the familiar animals of the present.

The only animals now in existence which possess a hand at all comparable to that of the Pterodactyles are the curious flying quadrupeds which we all know as bats, and in these the resemblance is accompanied by striking differences. If we look at the hand of a bat (Fig. 6, C), we see that all the five fingers are present, the thumb being very small, and furnished with a hooked claw; while the other four fingers are of immense length, and are clawless. The hand, therefore, is like that of the Pterodactyl (Fig. 5, A), except that in the latter three of the four fingers are short and clawed, and only one finger is lengthened out and clawless. We know, however, what function is discharged by the elongated and clawless fingers of the hand of the bat. We know that they serve for the support of a delicate expansion of the skin, or "wing," which stretches between the fore and hind legs, and is attached to the sides of the body, while a continuation of it is sometimes found between the hind legs, inclosing the tail. We know that the long fingers of the hand are the principal agents by which this "flying-membrane" can be folded up or expanded for use, as the animal may desire; and we know that the membrane thus expanded and supported can be made by the muscles of the arms to beat the air in successive strokes, thus conferring upon the animal the power of genuine "flight." Judging, then, from what we know of the bats, we should be justified in inferring that the single greatly elongated and clawless finger of the Pterodactyles served for the support of a delicate "flying-membrane," or lateral expansion of the integument, springing from the sides of the body, attached to the fore and hind legs, and extending from the hind legs to the tail; and we should also be warranted in believing that this flying-membrane could be made by appropriate muscles to strike the air in the same manner as the "wing" of the bats. In Fig. 8 we have given a representation, after Professor Owen, of one of the Pterodactyles as it must have appeared

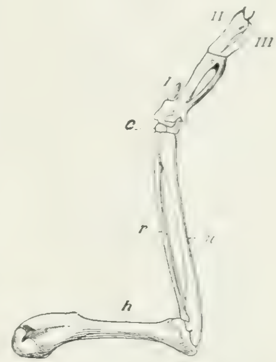

FIG. 7.—ARM AND HAND, *i.e.* WING, OF A BIRD.

h, *bone of upper arm*; *r* and *u*, *bones of fore-arm*; *c*, *bones of wrist*; *I*, *thumb*; *II*, *fore-finger*; *III*, *middle finger*.

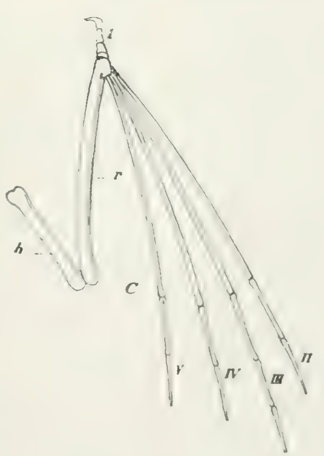

FIG. 6.—ARM AND HAND OF A BAT.

h, *bone of upper arm*; *r*, *bone of fore-arm*; *I*, *thumb*; *II*, *III*, *IV*, *fingers*; *V*, *little finger*.

in its living state; and from this the reader can at once judge of the form and proportions of the supposed flying-membrane of these animals. It follows further that, if this view as to the functions of the elongated finger of the hand of the Pterodactyles be a correct one, these animals must have been able to "fly" in as strict a sense as the birds and the bats; so that there is no real ground for comparison between the "flying-membrane" of the former and the lateral "parachutes" of such living reptiles as the "flying dragons"; the latter, as we have seen, have no power of true flight, but simply use the lateral folds of skin as supports in long leaps through the air.

It may be said, however, that this is all mere conjecture, and that we have no right to reason in this way. The sceptic may even ask, "Where is this flying-membrane? How is it that the bones have been found, and not the membrane? To this apparently plausible objection it must be urged that the flying-membrane which the Pterodactyles are believed to have possessed must have been so delicate that we could hardly expect reasonably that it should have been preserved along with the greatly less perishable bones. However, in the remains at Solenhofen, previously referred to, there are occasional traces of this very membrane—only an impression, of course, in the matrix below, but still a trace. Moreover, we possess very important collateral evidence proving that these animals were able to support themselves in the air. Thus, we find that the breast-bone of the Pterodactyles (Fig. 4, B) is furnished in front with a well-marked longitudinal ridge or keel of bone. A similar keel is found on the breast-bone of the flying birds, and also on that of the bats, and we know perfectly well what it means, and what is its function. We know, namely, that this keel upon the breast-bone is used for the attachment of the great muscles which move the wings; and the size of the keel is therefore a fair indication of the power of flight possessed by any bird, its size increasing in direct proportion to the strength of the muscles of the wings. We know that a few burrowing animals—such as the moles, in which the muscles of the arms are greatly developed—have a similar though less extensive keel upon the breast-bone; but as there is not the slightest ground for ascribing burrowing habits to the Pterodactyles, we are fully justified in believing that the keel upon the breast-bone indicates in their case the possession of powerful wing-muscles, and the consequent capacity for flight. Again, we know that the bones of the Pterodactyles were very light, and were hollow, their cavities being filled not with marrow, but with air. It is true that the bats, which possess the power of flight, have the bones filled with marrow, so that the presence of air in the bones is not absolutely essential to flight; but in all the flying-birds the bones are more or less extensively hollowed out into air-cavities, and we can hardly be wrong in concluding that the existence of similar cavities in the bones of the Pterodactyles indicates a similar mode of life for the latter.

Upon the whole, then, we may safely conclude that the Pterodactyles enjoyed the power of genuine flight, and that the apparatus by which they supported themselves in the air was a flying-membrane, essentially similiar to the "wing" of the bats, but differing in the fact that the chief agent in its expansion is a single elongated finger. It remains, accepting this as settled, to briefly consider the relationships which subsist between the Pterodactyles on the one hand, and the bats, the birds, and the reptiles on the other hand. From the bats, as we have seen, the Pterodactyles are distinguished by the different structure of the hand; but a distinction of more vital importance

is to be found in the fact that the former possessed no air-cavities in the bones (this implying a very important difference in the structure of the breathing organs), while the skull of the latter is built upon an entirely different plan from that which we find in the bats. We may, therefore, decide without hesitation that the Pterodactyles cannot be placed in the neighbourhood of the bats, and, indeed, cannot be associated with the true quadrupeds ("mammals") at all. To the birds the Pterodactyles exhibit many points of affinity, as seen more especially in the general structure of the skull and neck, and in the presence of air-cavities in the bones. These resemblances, however, cannot be allowed to count for much as against the striking differences which separate these two groups. If the Pterodactyles were really related to the birds, they must have been warm-blooded animals; in which case—as strongly insisted upon by Owen—they must have possessed a non-conducting covering of feathers. We have, however, no evidence that they were provided with feathers or with any integumentary appendages of any kind; and we have the reasonable right to interpret this negative evidence in a positive light, seeing that the rocks in which Pterodactyles are most abundant have actually yielded the well-preserved traces of feathers in connection with the bones of true birds. There is, therefore, every probability that the skin of the Pterodactyles was naked, a condition of things incompatible—except in animals capable of clothing themselves artificially—with the possession of hot blood. Moreover, the apparatus of flight in the Pterodactyles and the birds is respectively very different. In the former, the animal supported itself in the air by a "flying-membrane," carried principally by one elongated finger. In the latter, the fore-limb, or "wing," is only furnished with two fingers and a rudimentary thumb, and its entire structure is specially modified (Fig. 7) for the attachment of a series of quill-feathers, which constitute the actual apparatus of flight.

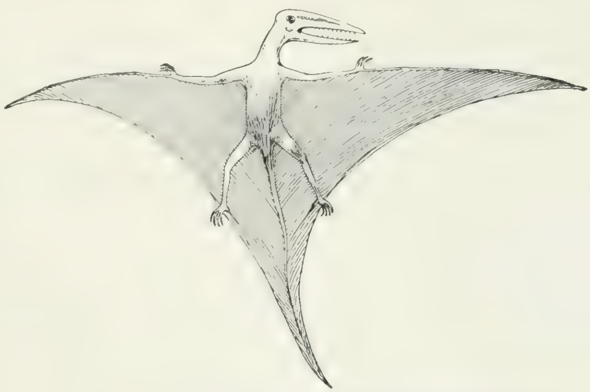

FIG. 8.—A PTERODACTYL (*DIMORPHODON MACRONYX*) RECONSTRUCTED.
(*After Owen.*)

This gives an idea of what this now extinct animal was like in shape and appearance. The animal was many times bigger than in the picture. This Pterodactyl was remarkable for the length of its tail.

On the other hand, the balance of evidence at the present moment is very decidedly in favour of our considering the Pterodactyles as truly referable to the class of the reptiles, and to be, therefore, essentially related to such existing animals as the lizards and the crocodiles. Not only do they agree with the reptiles in very many important points connected with their skeleton, but the fact that they were destitute of either feathers or hair, and that they were therefore cold-blooded, will hardly permit us to associate them closely with any other known group of animals.

If this conclusion be accepted—and few now entertain views essentially different—we are presented in the Pterodactyles with one of the most remarkable of many extinct types of reptilian life. The power of flight, conditioned by the possession of a bat-like wing-membrane,

supported upon one greatly elongated finger, and the possession of hollow bones filled with air, are points in which the Pterodactyles differ from all known reptiles; and they must, therefore, be regarded as constituting a group quite apart, within the limits of the class to which they belong. Nor can their general appearance when alive have been any more in accordance with our ordinary notions than their internal structure. They do not take the place of the true birds during the Secondary period, for we know that these existed as well; but they seem to have been the principal denizens of the air at this epoch of the history of the earth. The smaller ones may, perhaps, have lived upon insects; but the larger ones probably subsisted upon fish, their toothed jaws serving admirably to enable them to retain a firm hold of their slippery prey. The giants of the order (with skulls three feet in length and wings twenty-five or thirty feet in expanse) appear, however, to have been destitute of teeth, though it is probable that they, too, lived principally upon fish. It hardly needs a great stretch of the imagination, now that we know something of the structure of these wonderful reptiles, to call up before our mind's eye a scene on one of the coasts of the Oolitic or the Chalk Sea in which we may suppose the principal actors to be Pterodactyles. Each may fill up the details of such a scene as best pleases him. In any case, the predominant feature of the picture will be found in the presence of these weird and uncanny creatures, some sitting on a projecting point of rock, watching with glittering eye the movements of the fish in the clear blue water below; some beating with leathern pinions the dusky air, hovering above the unruffled surface of the ocean, and anon darting down with rapid swoop upon their hapless prey; and others, possibly with many a dissonant shriek, winging their way steadily to some distant roosting-place among the cliffs.

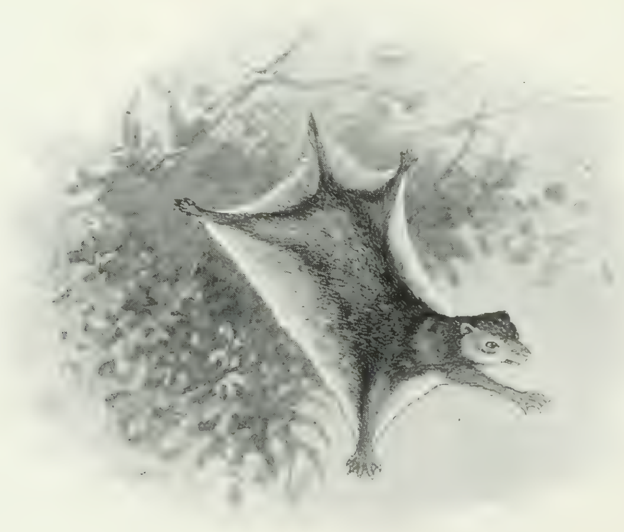

FIG. 9.—FLYING LEMUR (*GALEOPITHECUS VOLANS*).

These pretty little animals, aided by the membrane that stretches from their front to their hind legs, can take enormous leaps.

THE WIZARD ELECTRICITY.—III.

THE ELECTRIC LIGHT.

BY FRANK C. WEEDON.

THE capture and control of the modern "slave of the lamp," electricity, must surely be reckoned among the greatest triumphs of the human

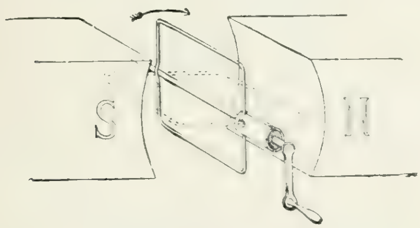

FIG. I.—A RECTANGLE OF WIRE ROTATED BETWEEN THE POLES OF A MAGNET (N. AND S.).

intellect. The beginning of this control may be dated from 1831, when Faraday discovered how induced currents of electricity could be produced. He found that if an electric conductor is in a magnetic field, any movement which *alters* the number of lines of force passing through that conductor is attended by the production in it of an electric current. The currents obtained in the original experiments were very small, but they were identical, in other respects, with the output of the powerful dynamos of recent date.

We will endeavour to trace the outline of the development of the dynamo from its small beginnings, and then try to show how the current is conveyed along conducting wires and made to produce light when it is wanted.

In the illustration (Fig. 1) a rectangle of wire can be rotated by means of the handle between the poles N. and S. of a magnet. The lines of force run straight across the gap from one pole to the other, so that the wire in being revolved cuts across the lines of force. Accordingly, an electric current tends to flow along the wire.

The tendency to send an electric current depends on the *rate* at which the lines of force are cut. It is clear that when the upper portion begins to move from its highest position it will cut through the lines at a much slower rate than when the rectangle is horizontal, so that the current produced would steadily grow from a minimum to a maximum, and then decrease steadily to the minimum. Again, it should be noted that the direction of the induced current depends upon the *direction* in which the conductor is moving. Consequently, in the second half of the revolution the current will flow in the opposite direction to the current produced in the first half of the rotation. So that, if we continue to rotate the rectangle, we shall produce currents *alternating* in direction.

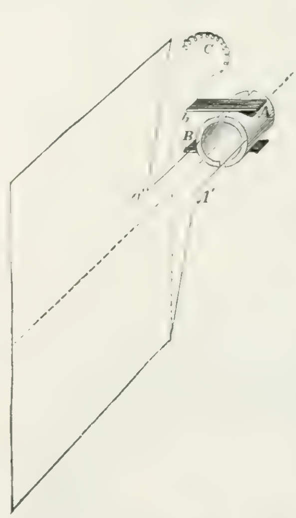

FIG. 2.—A SPLIT-RING COMMUTATOR: LOOPS FOR CONTINUOUS CURRENTS.

A' a'. Ends of rectangle.
A. Split tube.
B b. Brushes.
C. Circuit of current.

It is quite easy to arrange that the rotating conductor does not form a complete electric path, and to close the circuit by a wire which remains at rest. Then the currents will flow through this external circuit, and, by a simple device, the alternating

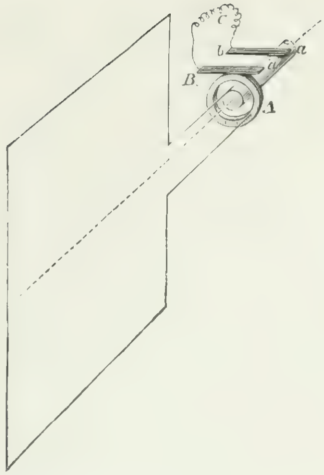

FIG. 3.—CONNECTION OF LOOPS FOR CONTINUOUS CURRENTS.

A. Split tube; a. Spindle.
B b. Brushes.
C. Circuit of current.

current in the rectangle can be converted into a continuous current. The ends of the rectangle are joined to the two halves of a split tube (Fig. 2). This split tube is fitted to the spindle on which the rectangle revolves in such a way that the two portions are insulated from each other. There are two "brushes" so arranged that the induced currents pass through them to the circuit *c* from the segments, and the segments change brushes just as the rectangle passes its vertical position—that is, where the induced current is zero. This device is called a "split-ring commutator."

If the currents are taken from the rectangle and supplied to the circuit *c*, as shown in Fig. 3, the currents in *c* will be *alternating currents*.

We have thus two types of machines supplying electricity—*continuous current* and *alternating current* dynamos.

Turning to the rectangle (Fig. 1) again, the fluctuations in the current produced by the rotation are in many cases very undesirable. The rotating part—or *armature*—of a dynamo is accordingly never a single loop of wire. Very many patterns of armature are now made, and they may be divided into two main groups—*open-coil armatures* and *closed-coil armatures*. In the first of these types the ends of the separate windings are not brought together except by means of the commutators, while in the closed-coil armatures all the windings are joined, forming a continuous circuit.

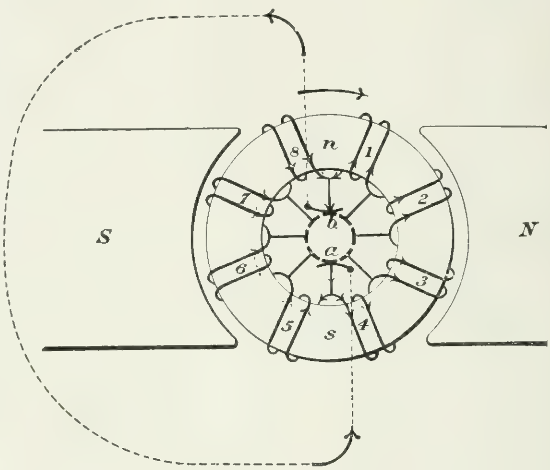

FIG. 5.—DIAGRAM OF WINDING OF RING ARMATURE.

N and S. Poles of a magnet.
1—8. Pairs of coils.
a b. Split tube.

Fig. 4 shows an open-coil armature partly wound. The coils, which are diametrically opposite, are connected in pairs, and to each pair of coils is a commutator, so that an armature of eight coils would have four commutators. The closed-coil armatures may be divided into two classes—*ring armatures* and *drum armatures*.

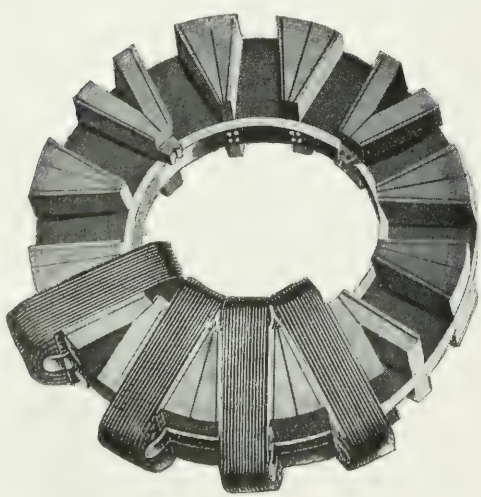

FIG. 4.—BRUSH RING, PARTLY WOUND.

Figs. 5 and 6 show diagrammatically the winding of ring and drum armatures.

The armature, as we have seen, generates an electric current when it revolves

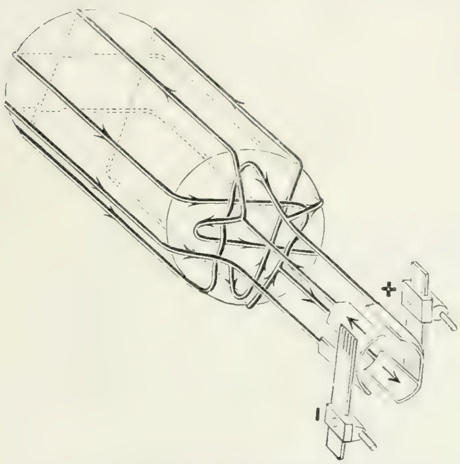

FIG. 6.—WINDING OF A DRUM ARMATURE.

in a magnetic field. In the early machines the armature revolved between the poles of permanent magnets of steel, but this plan is no longer followed.

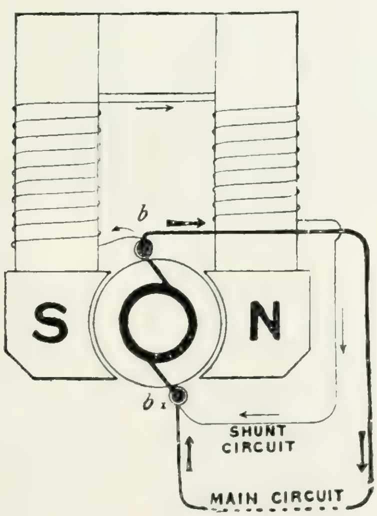

FIG. 7.—A SHUNT DYNAMO.

In place of the steel magnets we find, in modern dynamos, field-magnets, formed of soft iron and generally horseshoe shaped.

Dynamos may be divided into three classes, according to the winding of the field-magnets :—

(1) Shunt dynamos (Fig. 7).
(2) Series dynamos (Fig. 8).
(3) Compound dynamos.

In the shunt-wound dynamo part of the current is "shunted" off to excite the field-magnets, the remainder being supplied to the external circuit. But, it may be asked, how is electricity generated in the first revolution of the armature? The answer is that the soft iron of the field-magnets never loses entirely its magnetisation, so that, even in the first

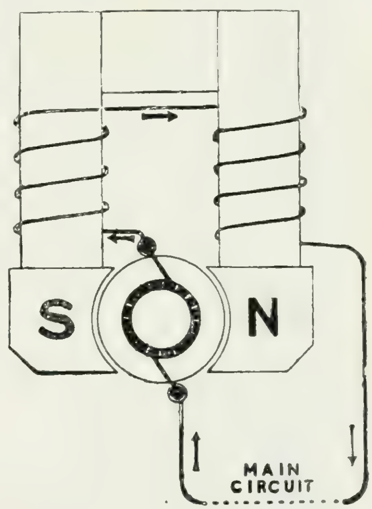

FIG. 8.—A SERIES DYNAMO.

revolution of the armature coils, small induced currents are produced. The shunted portion is sent through the coils magnetising the field-magnet cores, which thereby produce stronger currents in the armature, and so on, until the field-magnets are worked up to their highest magnetic strength.

A shunt-wound dynamo (Fig. 7) has an important advantage. If we increase the resistance in the external circuit, we cause more current to be shunted round the field-magnets. This produces a larger current, so that to some extent a shunt-wound dynamo is *self-regulating*.

In the series-wound dynamos (Fig. 8) all the current passes "in series" through the armature coils and through the external resistance. It is clear that, if this external resistance varies, the output of the machine will alter also. If the resistance becomes greater, the current magnetising the field-magnets will diminish, and, consequently, the dynamo will generate less. On the other hand, if the external resistance becomes smaller, the current may become so great as to heat the conducting wires till they fuse.

The compound winding is a combination of the above two methods. There are two coils wound on the field-magnets—one which carries the external current, and the other which conveys a shunted portion. This arrangement makes the dynamo automatically keep its voltage constant when the external resistance varies. The details of the dynamo shown in Fig. 9 will now readily be understood.

The method of conveying the electricity from the dynamo to wherever it may be wanted next demands attention. There must always be a complete electric circuit, and the easiest method to understand is that in which the circuit is simple and continuous. Lamps lighted on this circuit are said to be "in series," and the figure (Fig. 10) makes the arrangement quite plain.

The glow lamps with which we are familiar are usually grouped "in parallel." Insulated copper conductors convey the current from the dynamo to the lamps. There are two principal arrangements for the lighting of lamps "in parallel"—the "two-wire" and the "three-wire" systems. The diagram (Fig. 11) shows lamps lighted on the two-wire system. The mains are kept at a constant pressure, and each lamp has its own connection with the mains. Switching a lamp on or off, consequently, does not affect the other lamps; it only affects the current taken from the dynamo.

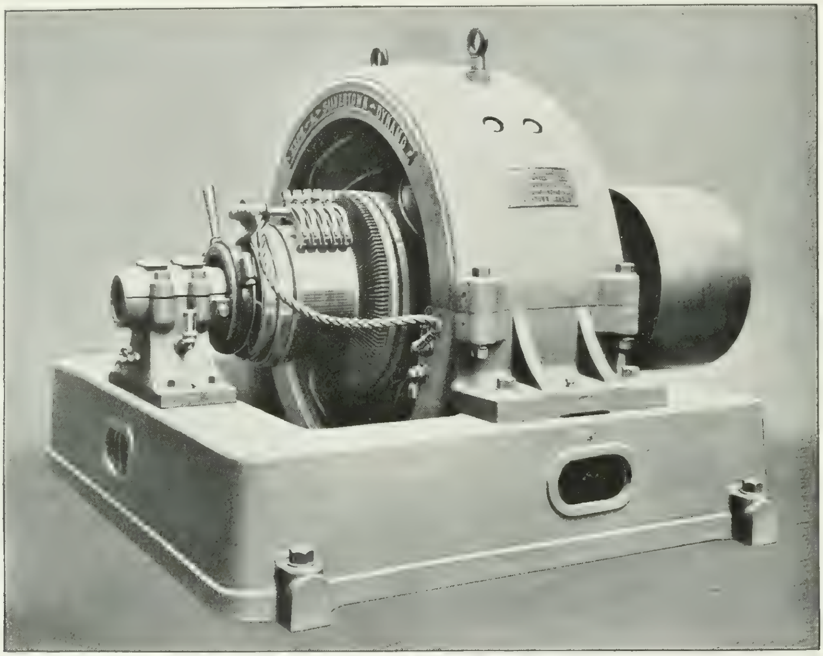

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FIG. 9.—TYPE K., SILVERTON DYNAMO

The three-wire system was devised to effect economy in the copper of the mains.

The conductors are called the *outer*, *inner*, and *middle* wires, and the con-

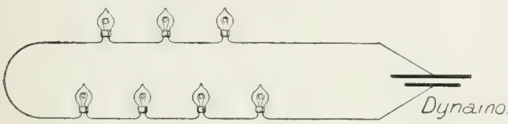

FIG. 10.—DIAGRAM SHOWING LAMPS IN SERIES.
By this method the lamps are situated along a simple continuous circuit.

sumers' lamp is connected between the middle and outer or middle and inner mains (Fig. 12).

When the pressures of the outer and inner wires are equal there is no current along the middle wire. Usually this condition is not obtained, and the middle wire has to convey the difference of current required on the two sides. It follows that the middle conductor may be smaller than the other two. The conductors are usually copper cables with insulating coverings of india-rubber, and protected by stout braidings or armouring where injury is to be expected. Fig. 14 shows how insulated cables are laid: most dwellers in towns will be familiar with this part of the process.

If our dynamo is some distance from the place where the electricity is to be

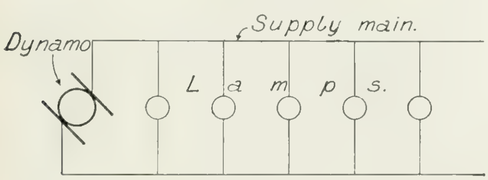

FIG. 11.—LAMPS UPON THE TWO-WIRE SYSTEM.
Here each lamp has a separate connection with the mains, and any one may be "switched" off without affecting the others.

used, the length of copper wire forming the circuit becomes a serious item of expenditure. We see by Ohm's law that the current is large when the resistance of the circuit is small, and that to get a large current from the dynamo we must use thick wires. There is another way, and that is to drive the dynamo fast, so as to make it generate electricity at high pressure. Then trouble arises from friction of the brushes. Now, the brushes are not necessary unless we wish to obtain a continuous current. Accordingly, for the sake of economy of conducting wire, electricity for lighting purposes is supplied from *alternators*. With these machines, and good insulation, very high pressures may safely and easily be obtained.

The electric current is not always conveyed directly from the dynamos to the lamps. Where the area to be supplied with electricity is large, it is clear that the length of cables will be great, and, if the copper conductors are thick, the cost

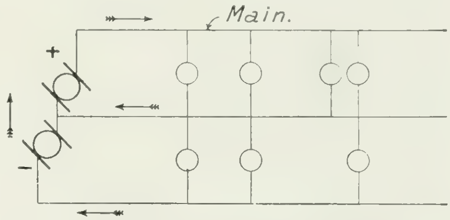

FIG. 12.—LAMPS UPON THE THREE-WIRE SYSTEM.

will be considerable. This expenditure can be cut down by using thinner conductors, in which case the current must be supplied at high pressure. There are two objections to the distribution of electric energy in high-pressure currents. One is that with high *potentials* it is not easy to prevent leakage; and the other—the more serious objection to the public—is that conductors conveying these high-pressure currents are dangerous to those who are inexperienced in electrical science. The latter difficulty is overcome by the use of special apparatus called *transformers*.

There are two chief kinds of transformers—those used to transform *continuous*, and those used with *alternating* currents. We will consider continuous current transformers first (*see* Fig. 13).

Within certain limits, we can control the pressure at which a dynamo will

supply current by suitably adjusting the winding. (It should be borne in mind that, with any particular machine, if we wind for high voltage we shall get low current, and *vice versâ.*) There is another fact of enormous importance in connection with a dynamo. Used in the ordinary way, the armature is caused to rotate, and an electric current flows along a conductor from one terminal to another. If, however, instead of taking a current from a working machine, we *supply current* to the terminals of a dynamo which is at a standstill, we shall find that the armature will revolve; and if we connect by a band or gearing this revolving armature with a machine—such as a sewing machine or lathe—we shall make the electric energy do work.

When the machine is used to supply electric current it is called a *dynamo*, and when it is used to change electrical energy into mechanical energy it is called a *motor*.

A dynamo and a motor used together will make a transformer. Suppose, as is generally the case, we wish to transform continuous current at *high* into continuous current at *low* voltages. The high-pressure current is made to work a motor. This in turn drives the armature of a dynamo, and by suitably adjusting the winding of the latter the current which it supplies will be at the voltage desired. A motor may drive two dynamos, one on each side of it.

The principle on which alternating current transformers are made may readily be understood. Two coils of insulated wire are separately wound on a core of soft iron; one coil consisting of many turns of fine wire, and the other of a few turns of stout wire. If the thin wire coil is connected with the alternator generating the high pressure currents, induced alternating currents will be formed in the second coil. These induced currents will be larger than those in the thin wire coil, but will have a smaller pressure, according to the ratio of the two windings.

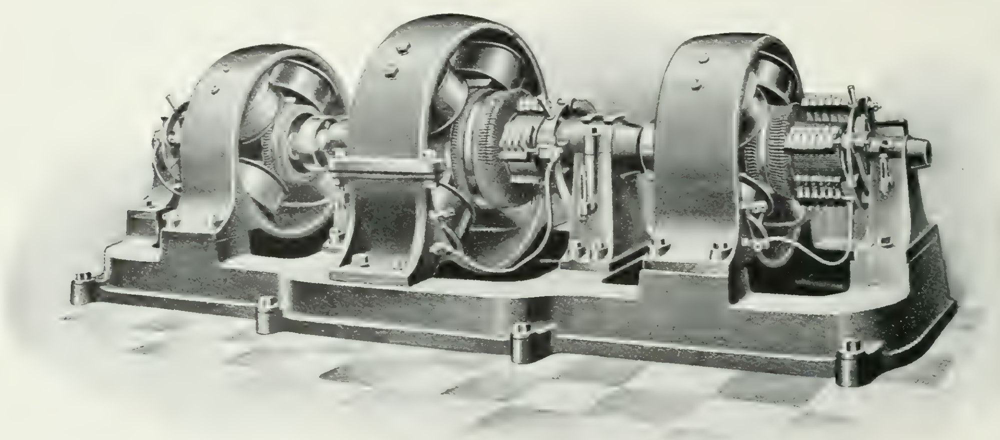

Photo supplied by General Electric Co., Ltd.

FIG. 13.—CONTINUOUS CURRENT TRANSFORMER.

The high-tension currents supplied are often *alternating currents*, and before these are available for the working of tramways, electro-plating, and the charging of storage batteries, not only has the *potential* to be reduced, but the alternating currents must be converted into a continuous current.

Fig. 15 is a diagram showing how an

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FIG. 14.—LAYING CABLES FOR ELECTRIC LIGHT IN THE STRAND.

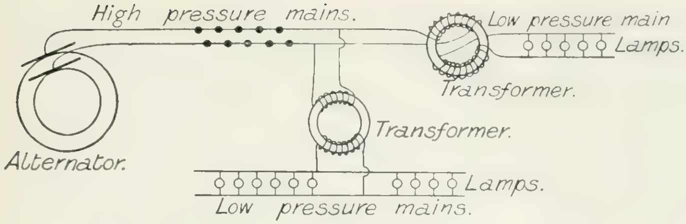

FIG. 15.—DIAGRAM OF DISTRIBUTION OF CURRENT.

alternating current of high pressure is conveyed a distance by thin mains, and transformed near where it is to be used into low-pressure currents, either continuous or alternating, as may be necessary.

If it is desired to convert a high tension alternating into a low tension continuous current, more complicated machinery is necessary. The alternating current is led into a motor which is so constructed that its armature will revolve under the influence of alternating currents. This motor drives a dynamo which yields the continuous current.

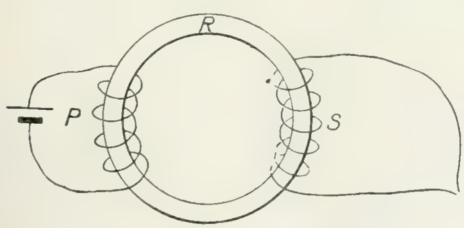

FIG. 16.—A RING TRANSFORMER.

The transformers which alter both potential and direction are costly, and require attention. Recently an American invention has been introduced which promises to reduce greatly the cost of transforming. It is called, after its inventor, the Hewitt static converter. The apparatus, which is extremely simple and ought to be eventually inexpensive, is shown in Fig. 17. There is a tube—from which the air has been exhausted—containing mercury and a positive electrode for each phase of the alternating current. There is one negative electrode, and the general effect is that the alternating current is supplied to the tube and is conducted by the mercury vapour to the negative terminal. It thence passes by a wire through the tube to the exterior, and flows as a *continuous current.* Used with a transformer of the type illustrated by the ring in Fig. 16, great economy is promised.

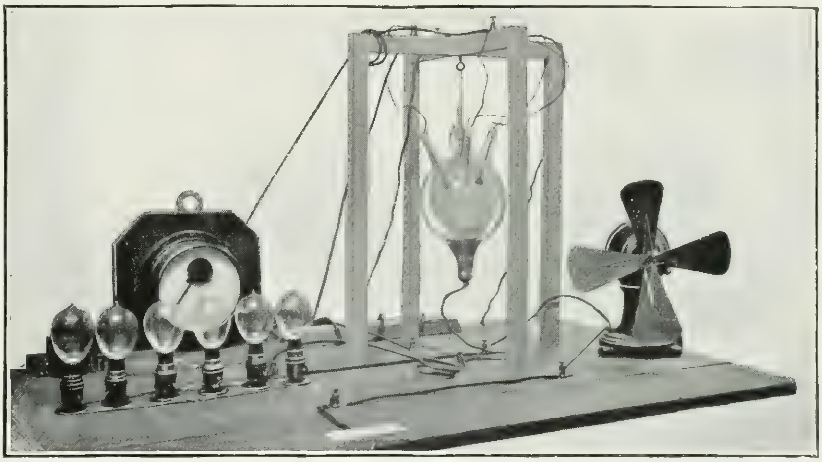

FIG. 17.—HEWITT STATIC CONVERTER.

Having produced the electric current and distributed it at a suitable pressure, the lamps to be used require attention. There are two chief kinds of lamp at present employed—*arc lamps* and *glow* or *incandescent lamps*—and we will briefly deal with each type.

Carbon is a conductor of electricity,

and if a circuit is formed (as shown in Fig. 18) having two carbon rods in it there will be a current. If the carbons are then separated a little way, the electricity will spark across the gap, a path or arc of glowing vapour is formed, and, the carbon points becoming white hot, a dazzling light is produced.

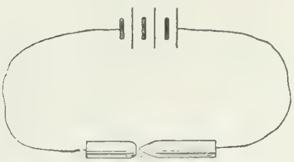

FIG. 18.—AN ELECTRIC CIRCUIT, WITH CARBON RODS.

are made self-adjusting by the aid of two electro-magnets. As the carbons burn, the resistance of that part of the circuit is increased by the lengthening of the gap. This alters the current, which flows round a core of iron, and attracts magnetically another piece of iron, which, being fixed to a lever, adjusts the distance of the carbons.

The principle of the *glow lamp* is very

FIG. 19.—AN ARC LAMP.

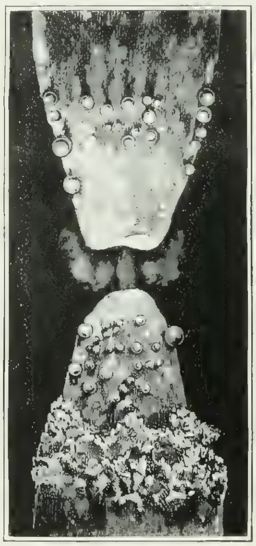

FIG. 20.—CARBON POINTS FOR ARC LIGHT.

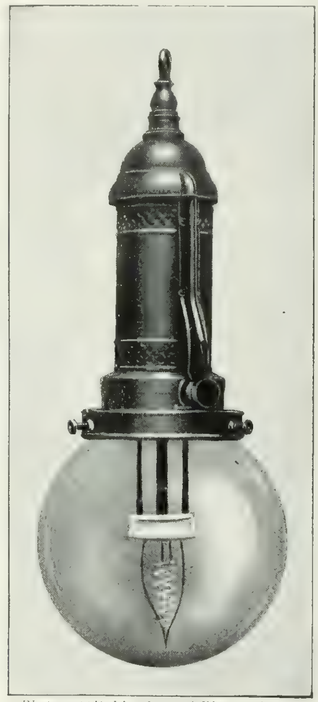

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FIG. 21.—NERNST LAMP.

This fact is made use of in the construction of arc lamps (Fig. 19).

When continuous currents are used with these lamps the positive carbon is burnt, so that a cavity is formed, as shown in Fig. 20. With alternating currents both carbons assume the appearance of the upper one in this figure. This burning away of the carbon is the chief difficulty to be overcome in the construction of the lamp: some modern arc lamps have the carbons enclosed in a globe. In most cases the carbons

simple. Any conductor is heated by the passage through it of an electric current, and if its resistance and the current are sufficiently high the heat may make the conductor white-hot, and so give out light. The conductor usually employed is a thread of carbon. This would speedily burn away in the air, and in order to prevent this the filament is enclosed in a glass bulb, and the air pumped out.

A glow lamp is shown in Fig. 24. Each end of the filament is connected with a separate piece of platinum in the upper

part of the lamp, by which current is admitted when the lamp is attached to its holder. These filaments are fragile, because of the thinness necessary to permit of their being made white-hot.

Photo supplied by Messrs. Callender & Co.

FIG. 22.—LAYING ELECTRIC LIGHT CABLES UNDER A RIVER BED.

The conducting strands of soft copper wire in these cables are protected by successive layers of jute fibre, bitumen, lead sheathing, and steel armour. The steel armour is composed of two tapes or ribbons of mild steel. The first tape is wound on in such a way as to leave a space between the convolutions, and the second tape is arranged to cover these spaces. After being armoured the cable is passed through a bath of special bitumen compound to cover the steel.

The Nernst lamp is shown in Fig. 21. It resembles the ordinary glow lamp in that the light is given out by a solid made white-hot by the electric currents. The filament, or "glower," as it is called, is a rod of material similar to that used in the Welsbach gas mantles. A peculiarity of this substance is that when cold its resistance to the electric current is great, but when made hot it becomes a conductor. The passage of a current raises its temperature still higher, and when sufficiently heated it emits a white light of great brilliancy. The "glower" will stand a much higher temperature than the carbon filament of the ordinary glow lamp, and it is not necessary to exhaust the air from the globe in which it is fixed. There are three difficulties overcome in the construction of this lamp, which has been described as "a marvel of ingenuity": a spiral of platinum wire is wound round the "glower" to make

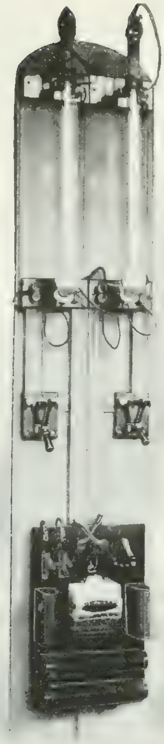


FIG. 23.—SOMETHING FOR PHOTOGRAPHERS: THE HEWITT MERCURY VAPOUR LAMP.

The mercury in the tube is vaporised, the vapour becomes incandescent, and a bright light is given off.

it sufficiently hot to become a conductor of electricity, an electro-magnetic "cut-out" prevents the current from flowing in this spiral any longer than necessary, and a suitable resistance is arranged "in series" with the "glower" so that the brilliancy of the light is maintained.

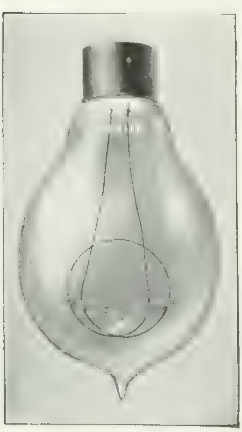


FIG. 24. — ROBERTSON GLOW LAMP.

The Hewitt mercury vapour lamp (Fig. 23) differs from all other lamps hitherto put on the market. Platinum wires are passed through the ends of a glass tube into which a little mercury is poured, and the air is then pumped out. The two ends of a high-pressure circuit are attached to the two platinum wires, and a discharge takes place across the vapour of mercury in the tube. This has the effect of making the vapour much more conducting, so that a low-pressure current of 50 to 100 volts can be carried across the tube. The vapour is thereby made incandescent, and gives out a bright and diffused light. It is, however, deficient in red rays, making the light unsuitable for domestic purposes; but in all cases where accurate colour value is not essential the lamp should have a great future.

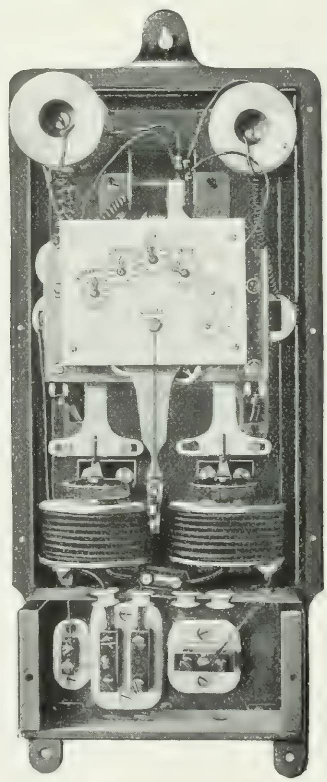


FIG. 25.—THE ARON METER.

Photographers especially will eagerly welcome this lamp, because the light is rich in rays which photography requires, and also because the light does not cast

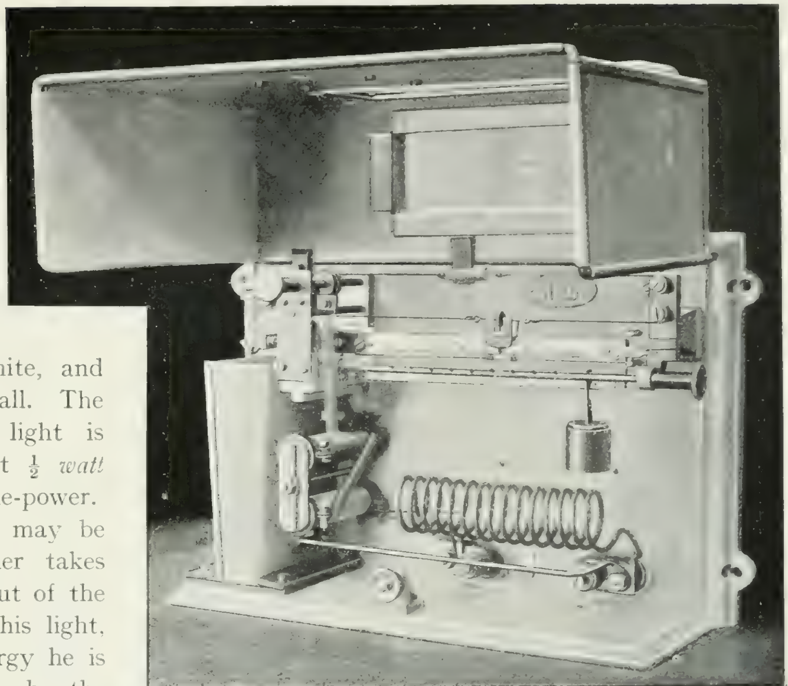


FIG. 26.—THE SCHATTNER STANDARD METER, WITH COVER OPEN.

the sharp black shadows produced by the arc light. The lamps may be made in any shape, and in size may vary from 3 inches to 12 feet in length. The life of the lamp is practically infinite, and the initial cost small. The efficiency of the light is great, being about ½ *watt* per spherical candle-power.

Whatever lamp may be used, the consumer takes electrical energy out of the system to obtain his light, and for this energy he is called upon to pay by the company supplying the current. To measure his indebtedness an *electricity meter* is employed. There are many kinds of electricity meters now in use, but if we understand the construction of the leading types it will not be difficult to make out the working of any particular instrument. We will first consider what it is that an electricity meter measures.

We have compared an electric current to a stream of water. Now, water falling from a height will set a turbine in motion, and the water-power of the turbine depends partly upon the quantity of water and partly upon the height from which it falls. The work that could be done by the falling water would depend, therefore, on three things—the *height* of the waterfall, the *quantity of water*, and the *time* the turbine was running.

If, instead of the turbine or water motor worked by falling water, we use an electric motor, we can do work which will depend upon the *current*, the *pressure*, and the *time*. The product of current and pressure gives the electric power, the unit of which is accordingly the power of a current of 1 *ampère* driven by an electric pressure of 1 *volt*.* This is called a *watt*. The unit of electrical supply for which consumers pay is the 1,000 *watt-hour*, or, as it is called, the *kilowatt-hour*. This is the Board of Trade unit, for which not more than eightpence may be charged.

An electricity meter, consequently, serves its purpose if it registers current, voltage, and time of supply. Fig. 25 represents the Aron meter. It resembles an ordinary clock with the bob of the pendulum replaced by a coil of fine wire. This swings within a coil of thick wire so arranged that the magnetic pull on the pendulum when the current is flowing is proportional to the watts. The clock will err in time-keeping in a manner that depends upon the watts. A second

* See No. II. of the series, "How Electricity is Measured," CASSELL'S POPULAR SCIENCE, Vol. I., p. 173.

clock is geared to the first, so that the combination will record, by a series of dials, the kilo-watt-hours.

The Elihu-Thomson energy meter represents another type of electricity meter. It is an electric motor so constructed that the speed is proportional to the watts. To secure this the whole current is passed through the thick coils and a shunt current is sent through the coils of the armature. A copper disc attached to the armature spindle revolves between permanent magnets, and sets up induced "eddy" currents in the disc, and these set up an opposition to the rotation which is proportional to the speed of rotation. The indications of the dials connected with a train of wheels set in motion by the spindle can thus be adjusted to register units of electricity consumed.

By permission of Messrs. Callendar & Co.

FIG. 27.—LAYING ELECTRIC LIGHT CABLES.

Photo supplied by Messrs. Callendar & Co.

Three systems are shown here side by side

FIG. 28.—LAYING CABLES FOR ELECTRIC LIGHT.

The Schattner standard meter is shown at Fig. 26.

We have seen that the electric energy to be measured depends upon pressure, current, and time. If, as required by law, the pressure is constant, the purpose of a meter will be achieved by measuring current and time. But the

quantity of water passing under a bridge is the product of the number of gallons passing per minute multiplied by the number of minutes—that is, *current* $\times$ *time* $=$ *quantity*. This is equally true of electric currents, so that if we measure the quantity of electricity passing through a lamp at steady pressure—if we know what that pressure is—we measure the electric energy indirectly. This is accomplished in the *chemical meters*. The principle of these meters is the law of electro-plating—viz. that the weight of metal plated is proportional to the quantity of electricity passing through the electro-plating bath. A solution of sulphate of copper is used, and the weight of copper plated measures the electricity. [Students may be referred to Dr. Walmsley's "Electricity in the Service of Man."]

FIG. 29.—BATTERSEA BOROUGH COUNCIL ELECTRIC LIGHT STATION.

THE MINOR PLANETS.

THE chief planets of the solar system were found to revolve (long before the telescope revealed the smaller members of the series) at approximately regular distances from each other in the order of outward progression, and it was a fact incidentally referred to by Kepler that this harmony of position was disturbed in the case of Mars and Jupiter, between which there came a great void in the interplanetary spaces. The celebrated "law" attributed to Bode (but which really had its origin in Professor Titius, of Wittenberg), by means of which the relative distances of the planets were aptly represented, pointed distinctly to the assumption that an unknown planet revolved in the wide interval separating Mars from Jupiter (Fig. 1). Taking the solar distance of Saturn (which was considered the most distant planet at the time of which we are speaking) at 100 parts, then the distance of Mercury is 4, of Venus $4 + 3 = 7$, of the Earth $4 + 6 = 10$, and of Mars $4 + 12 = 16$, but from Mars we have to leap over a tremendous gap in the sequence of orbits before we come to Jupiter at $4 + 48 = 52$. Midway in the interval we get $4 + 24 = 28$, and here it seemed from the analogies of the law that a planet was wanting. In order to show the alleged correspondences, let us take the numbers—

FIG. 1.—RELATIVE POSITION OF PLANETARY ORBITS.

The dotted circle shows the position assigned, prior to 1801, to the orbit of an "unknown planet."

0 3 6
12 24
48 96

which, counting from the second, exhibit an increase of double value at each step; adding 4 in every instance, we have—

4 7 10
16 28
52 100

and these figures show a very remarkable coincidence with the actual planetary distances computed from observation (the Earth's distance being considered as 10) as follows:—

3·87	7·23	10·00	15·23
☿	♀	⊕	♂
void	52·03	95·39	
	♃	♄	

Those among our forefathers who reposed faith in universal laws or analogies as a basis of prediction must here have found

an attractive subject for speculation. This law of Titius conformed with remarkable closeness to the relative distances of the planets, except in one instance, and this of so striking and distinct a nature as to lead directly to the inference that a large planet or series of planets remained undiscovered. Kepler wrote in the introduction to one of his works : " I have become bolder, and now place a new planet between Jupiter and Mars, as well as another between Venus and Mercury ; probably it is the extreme smallness of both which has caused them to remain unseen." Titius himself, speaking of the great vacancy between Mars and Jupiter, expressed his conviction that " we must not doubt that it is occupied ; it may be by the hitherto undiscovered satellites of Mars, or perhaps Jupiter may have additional satellites that have never been seen by any telescope."

The so-called law of Bode in a modified form was applied by Wurm of Leonberg, who, adopting 387 as the distance of Mercury, 680 as that of Venus, and 1,000 that of the Earth, derived the following numbers :—

		True Distances.
Mercury	387	387
Venus	$387 + 293 = 680$	723
The Earth	$387 + 2 \times 293 = 973$	1,000
Mars	$387 + 4 \times 293 = 1,559$	1,523
Unknown Planet	$387 + 8 \times 293 = 2,731$	
Jupiter	$387 + 16 \times 293 = 5,075$	5,203
Saturn	$387 + 32 \times 293 = 9,763$	9.539
Uranus	$387 + 64 \times 293 = 19,139$	19,182

Though these figures present a very close approximation, they do not exactly coincide, and thus the alleged agreements were sometimes ridiculed as unworthy of more importance than should be attached to a purely accidental correspondence of numbers. But many remained dissatisfied ; they saw the wide breach in the successive folds of the planetary orbits, and, remembering the harmony and regularity which the whole mechanism of the solar system had exhibited, they ventured yet to predict the ultimate discovery of a planet which should restore the continuity of the series. True, the ancients had never seen the vestige of any such body, though they had pursued observations with a farseeing vigilance, and had even detected the fugitive Mercury. Obviously, therefore, if an unknown planet revolved between Mars and Jupiter it must be of extremely diminutive proportions, shining, in fact, with such feebleness as to elude the unassisted sight.

Towards the end of the eighteenth century a great impetus was given to observational astronomy by the eminently successful labours of William Herschel and his contemporaries, Schröter, Messier, and Olbers. The time had evidently come when something of an effort must be made towards the practical solution of the question. The suspected planet must be searched for in a systematic way, and by a corps of experienced observers. Accordingly, in 1800, an association was formed for the special purpose of exploring the zodiacal constellations, and critically examining the smaller stars there which might, by appearance or change of position, give indications of a planetary nature. The work was distributed amongst twenty-four observers ; each had one hour of right ascension (equivalent to 15° apportioned him, in which all the telescopic stars were to be subjected to a rigid scrutiny. Begun with such excellent method, and pursued with unabating energy, the search could not long prove fruitless. On January 1st, 1801, Professor Piazzi, of Palermo, discovered a faint stellar object in Taurus, which could not be identified with any star recorded in the catalogues. Observing it again on the following night, and finding that its exact position with regard to the neighbouring stars had certainly changed, there was no longer any doubt as to its real planetary nature,

though Piazzi at first mistook it for a comet on account of something unstellar in its appearance. He continued to observe it until the ensuing February 12th, when, however, he fell ill, and an abrupt termination was put to his observations. The new planet was then lost for a time, but Dr. Olbers, of Bremen, recovered it after diligent search, and its orbit was approximately computed from the available data obtained by him and Piazzi. The period assigned for its revolution was 1,652 days, at a mean distance from the Sun of 2·735, the Earth's distance being considered as 1. The new planet—for such it was incontestably proved to be—was named Ceres, and to those who had advocated the existence of such a body between Mars and Jupiter, the event afforded the most signal gratification, for nothing could be closer than the agreement between its predicted position and that actually derived from calculation. The law of Titius and Bode, as corrected by Wurm, indicated the place of the planet at 2·731; it was really found at 2·735, which is almost absolutely coincident. The great void separating Mars from Jupiter had disappeared, for exactly at the place where the analogies of the planetary distances had shown a planet to be wanting one was found, and of such small dimensions that it was no wonder that the expectant gaze of the ancient astronomers had been turned to it in vain.

The discovery of Ceres was the prelude to other important discoveries of a similar nature. Dr. Olbers, early in 1802, had been carefully noting the small stars of Virgo, and in March of that year, while awaiting the reappearance of Ceres after its conjunction with the sun, detected a faint body in a position which he could not reconcile with his former observations. This eventually proved to be a new planet which, on full investigation, displayed many points of similarity with that of Ceres, for its orbit and period were nearly identical, and it exhibited the same appearance and small proportions as that planet.

The assiduity of the observers was not relaxed on the discovery of these planets, which, indeed, caused them to redouble their efforts, so that on September 1st, 1804, a third was found, and on March 29th, 1807, a fourth. The former was detected by Professor Harding, of Lilienthal, Germany, and was named Juno. The latter was found by Dr. Olbers, and called Vesta, and was decidedly brighter than either of the others. When near opposition with the Sun, this planet is just perceptible to the naked eye, shining like a star of about the sixth magnitude. Thus four planets had been added to the known members of the solar system by the diligence with which the observations had been pursued; but, though the work was continued until 1816, no further discoveries were announced, and the search was finally given up. The results which had been achieved fully compensated for the labour involved. Four minor planets, forming a new order of bodies, had been detected between the orbits of Mars and Jupiter. Their elements, computed from the most recent data, are as follows :—

Planet.	Discovered.	Distance (♁ = 1).	Period Days.	Diameter Miles.	Star Mag.
Ceres	1801, Jan. 1	2·767	1681	488	7·7
Pallas	1802, Mar. 28	2·769	1683	304	8·0
Juno	1804, Sept. 1	2·669	1594	118	8·5
Vesta	1807, Mar. 29	2·362	1325	248	6·6

Sir William Herschel gave the name of asteroids to this new group of bodies, but they are sometimes more appropriately called planetoids, and of late years it has been superseded by the term "minor planets," which is becoming universally adopted as the most suitable title for this numerous and rapidly increasing class of bodies.

Upon the discovery of Ceres and Pallas, Olbers was led to a bold conjecture as to their origin. It was found that their two

orbits nearly intersected, that Ceres in her ascending node passed near Pallas, and he inferred from this that the two bodies might be the disrupted fragments of a large planet previously revolving in the broad interval which separates Mars and Jupiter, but which became shattered into pieces by some great natural calamity, and he further predicted the discovery "in the same region of many more such fragments." Were they the disintegrated

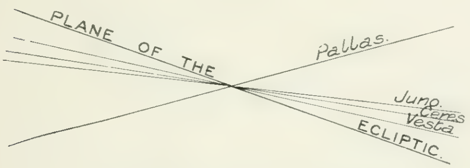


FIG. 2.—THE ORBITAL INCLINATIONS OF THE CHIEF MINOR PLANETS TO THE PLANE OF THE ECLIPTIC.

materials of one mass, he concluded that they must formerly have taken their departure from the same region, and their motions should exhibit "two common points of reunion, or two nodes in opposite parts of the heavens through which all the planetary fragments must sooner or later pass." On further investigation he found the position of these nodes to be in Virgo and Cetus, and it afforded singular evidence in favour of his remarkable conjecture when the planet Juno was afterwards discovered in Cetus, and Vesta in Virgo.

It must be admitted that the diminutive proportions of the new bodies, and the fact that they revolved at nearly similar distances from the sun in mutually intersecting orbits, aptly suggested the thesis of a close relationship, and pointed distinctly to the assumption that they owed their origin to the same source. Evidently they formed a special group of bodies with some anomalous features which sufficiently indicated their exceptional character, and signified that they could hardly be classed in the same category as the major planets of the solar system, which were vastly superior in size, and showed a totally different arrangement of orbits. The minor planets were found to revolve in singularly eccentric paths, inclined to the plane of the ecliptic at greater angles than any of the major planets (Fig. 2). Thus the inclination of Ceres is 10° 36′; of Pallas, 34° 43′; of Juno, 13° 1′; and of Vesta, 7° 8′; whereas that of Mars is only 1° 51′, and of Jupiter 1° 19′. The orbit of Pallas is, in fact, inclined at such a considerable angle that the planet may extend its excursions to some distance on either side of the ecliptic, and these eccentricities of motion have been held to favour Olber's theory of a fractured planet. Such a theory, though incapable of being demonstrated, and inferring, as it does, the occurrence at a far remote epoch of a stupendous phenomenon in the planetary spaces, is yet not altogether untenable when we consider the facts which have formed the basis of such a hypothesis, and the satisfactory explanation it gives to many curious results of observation. We are wholly ignorant of the vicissitudes to which the planets have been subject during the successive stages of their existence. At an early period of its creation, and before its mass had been tempered into solid coherence, the intra-Jovian planet may have collapsed under the influence of divellent forces acting upon it from within, and its fragments may have become distributed in a variety of new orbital paths around the sun.

Proctor, in a footnote to his "Old and New Astronomy," worked out the effect of the Earth's exploding in this manner on or about March 20th, at noon, Greenwich time. Then, he said, the greater part of South America would be driven forwards, almost along the Earth's previous track; the Indian Empire would go backwards; Africa and the Atlantic would tend sunwards, and the Pacific in the opposite direction; whilst England and the other European countries would be

impelled partly sunwards, and partly upwards and northwards, and would therefore travel on a track largely inclined to their former course, and similarly with the United States and Northern Asia. These fragments would thenceforward travel along inclined paths, crossing their original track ascendingly at the place where the explosion occurred. Similarly, Australia, South America, and South Africa would be blown downwards and southwards, and they would in future cross their original track along inclined paths descendingly at the point of explosion.

But as the nineteenth century wore to a close and the little planetoids became numbered by the hundred, it became increasingly evident that there was no single point of intersection for all their orbits, and yet these orbits are so crossed and interlinked that if they were really hoops or rings the lifting of one would take all the others with it. These entanglements might be accounted for to some extent by the mutual attractions of the bodies themselves, and by the pull of their giant neighbour Jupiter, who, indeed, seems to be responsible for gaps in the zone wherever the period of the planet that should fill that gap is commensurate by some simple relationship with his own period. Perhaps, as Professor Young suggests, though one explosion may not be held accountable for the zone of asteroids, yet a series of explosions might have been effective. Or if Sun and planets all took their origin in some great whirling nebula, as Laplace suggests, then the zone may be a planet marred in the making by the tidal influence of Jupiter, and analogous to the rings of Saturn. Yet we cannot deny the presence of explosive forces in the cosmos, and in some cases of a divellent force whose cause is unknown. The prominences on the Sun, the unexplained variation in brightness of many stars, the outbursts of "new" stars, like that in Cassiopeia in 1572, and, more striking still, the formation of a nebula, and the apparently enormous swiftness of motion of parts of that nebula, like that round the new star in Perseus in the autumn of 1901, are sufficient evidence that such forces are at work. Comets also have been seen to divide into separate parts, like that of Biela in 1845, and the comet of 1882.

Subsequent to the detection of the four minor planets—Ceres, Pallas, Juno, and Vesta—a remarkable lull occurred in the progress of planetary discoveries. There were absolutely no additions to our knowledge during the nearly forty years that ensued. In the meantime, improved star maps had been published, which, containing the smaller magnitudes, were of great practical utility in the search for minute planets. The Berlin charts, including stars up to the ninth or tenth magnitude, situated within 15° of the equator, superseded the less comprehensive charts of former observers, and though the twenty-four maps of which they consisted were not finally completed till 1859, a portion of them had been issued many years previously, and Herr Hencke, an amateur astronomer, at Driessen, in Prussia, availed himself of their aid in a renewed search for new planets. For a long time he was unsuccessful. Evidently the brighter planets had already been sought out, and those remaining were of such minute character as to readily elude the most vigilant eye. At length, however, on the night of December 8th, 1845, he found a suspicious object which he had not seen before in the same position, and which could not be reconciled with any star marked in his charts. This eventually proved to be another minor planet, and he followed up his success with a similar discovery on July 1st, 1847. They were very faint objects, not brighter than ninth magnitude stars when first

seen, and required a powerful glass to render their true character apparent.

These planets were the forerunners of similar bodies which have been detected since that epoch. Several hundreds have been discovered since Hencke announced his first success in 1845: in 1877 ten were discovered; in 1878 twelve; in 1879 no fewer than twenty, far exceeding the number found in any previous year, thus flatly falsifying the prophecy by Mr. G. F. Chambers in the first edition of his "Descriptive Astronomy" (1867), page 101, where he remarks that "for the present, at least, the number of new planets will not materially be augmented, and for this reason—the want of telescopes suitable and available for looking after them. All the brighter ones have evidently been found, and, speaking generally, each new one is fainter than its predecessors." These discoveries were largely due to Dr. C. H. F. Peters at Clinton, U.S.A., Signor Palisa at Pola, M. Goldschmidt at Paris, Mr. J. R. Hind at London, Dr. Luther at Bilk, Signor de Gasparis at Naples, Professor Watson at Ann Arbor, U.S.A., and M. Charlois at Nice.

But the discovery of a small planet was the least part of the work it entailed; far more difficult were the computing of its path, the perturbations of it by its fellow asteroids and by the neighbouring major planets, and the task of keeping it in view, so that it might not be again discovered and reckoned as still another new member of the system. Still the number continually grew, and a whole staff of computers were kept continually employed on them alone. One discoverer—Professor Watson—devised a fortune to the little family of twenty-two that had been gathered in by his telescope, lest, undowered, they should be thrown on the cold mercy of the astronomical world and neglected. But with regard to the others not thus provided for, the labour in following their movements was so enormous, their numbers increased so rapidly, and there seemed so small a prospect of any useful result, that "To what purpose is all this waste?" was being repeatedly asked.

And yet already, sixteen years earlier, the utilitarian value—if we may regard them from a purely terrestrial point of view—of the minor planets had been pointed out: the use they might be put to in solving what Airy had called the "noblest problem in astronomy," the distance of the Earth from the sun. In 1872 Professor Galle suggested that by the method of *diurnal parallaxes*, by the shift in position among the neighbouring stars of one of the nearer planetoids, as the observer on the Earth was carried by its rotation from sunset to sunrise, the parallax of the Sun itself might be obtained. Juno was thus tried by Lord Lindsay and Mr. David Gill in 1874, when they were conveniently stationed in Mauritius to observe the transit of Venus of that year. From 1888 to 1891 Dr. Gill, now at the Cape of Good Hope, organised more complete observations of Iris, Sappho, and Victoria, in concert with several other observers both in Europe and America, and obtained a parallax of 8·802″ ± ·005, corresponding to a semi-major axis of the Earth's orbit of 92,897,000 miles; a result more precise and trustworthy than any transit of Venus could ever give.

The principle of the diurnal method of parallax is very briefly as follows. Let P be a planet which by an observer at C, the centre of the Earth, would be seen in the direction $C\ P\ c$ on the sky (Fig. 3). An observer situated at E on the Earth's surface observes P at its rising and sees it in the direction $E\ P\ e$. Twelve hours later the rotation of the Earth has carried the observer at E round, so that he observes P at setting from the position W in the direction $W\ P\ w$. In the field of the

telescope this difference of position will be measured, by a micrometer, by the small shift of P with regard to all the stars visible in the same field. Now, if the planet is in opposition and we imagine that neither the Earth nor the planet has moved during the twelve hours between the observations, the shift of the planet from $P\ e$ to $P\ w$ will measure twice the horizontal parallax of the planet (Fig. 4). In practice the planet is observed on many mornings and evenings before and after its opposition, and small corrections have to be made for this, as well as for the movements of the two bodies in their respective orbits, and for the slight differences of refraction between the planet and the stars with which it is triangulated, and other small corrections. The same experiment has been made with Mars, which comes nearer to us than any of the minor planets mentioned; but this advantage is more than counterbalanced by the fact that Mars as seen in the telescope has a visible disc, and these minor planets have not; while the difficulty of finding the exact centre of a disc is liable to large uncertainty.

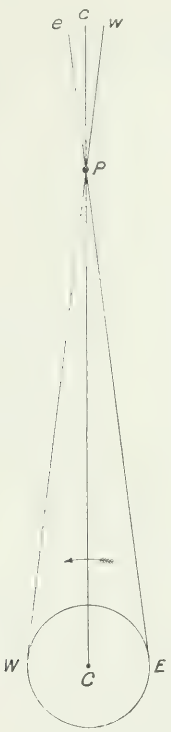


FIG. 3.—ILLUSTRATING THE MEANING OF "PARALLAX."

C, the centre of the earth.
C P, the line connecting the centre of the earth with P, the object viewed.
W and E, other points from which P is seen.
e c w, the continuation of the lines E C W.

The waste of time and instruments against which Proctor had protested went on unchanged for three years; the asteroid hunter made special telescopic charts of the star regions near the ecliptic, and if, on comparing his charts with the heavens, a stranger was detected, a few hours' watching showed if it moved out of its place, thus declaring itself a planetoid. But in 1891 Dr. Max Wolf, of Heidelberg, was

FIG. 4.—APPARENT MOVEMENT OF MINOR PLANETS AMONGST THE STARS, DUE TO "PARALLAX."

Pe Pw represents the extent of this "movement."

supplied by Miss C. Bruce with a large wide-angle camera and clock-driven mounting, and with this he took long-exposure photographs of the ecliptic regions of the sky of from 5° to 10° in diameter. The stars showed up on the negative as black dots; but a planet—if there was one in the field—moving at a different rate from the stars, showed as a dark streak. The first planet so discovered by Dr. Wolf he named "Brucia," in honour of Miss Bruce. Since then all other methods of search have been discontinued, and the photographic plate has proved such an efficient fishing-net that sometimes as many as five planets have registered themselves on a single plate, and two hundred new ones were brought in in the first ten years of its use. Up to the present the effort has been made to give a name to each member

of the asteroidal family, and also—as if it were one of the less reputable members of the celestial society, and had better be kept under lock and key for the good of its fellows—a number. Moreover, since the sensitive plate brings in new and old members indiscriminately, and it is a matter of time to consult the celestial records for its past history, each, while waiting its name and number, is provisionally designated by a letter or letters. In 1901 thirty-six new planets were discovered, but some of these did not receive permanent names, not having been sufficiently observed. The names given are feminine, except in the case of Eros; but the difficulty of finding an adequate supply has become so great that such titles as Photographica and Alleghenia were resorted to in a recent batch. The densest bulk of the planets cluster round the region marked out for the lost planet by Bode's law; but many individual planets lie widely apart from this. Thus, Henrietta has an aphelion distance of 4·31, Hilda of 4·63, and Andromache of 4·73; whilst Bononia has the greatest aphelion distance yet known of the entire family—namely, 4·74. Amongst those of nearest approach to the sun are Medusa, perihelion distance 1·88; Æthra, with perihelion distance 1·61, less than the aphelion distance of Mars; whilst Eros has its mean distance smaller than that of Mars. Pallas, the second in order of discovery, has the greatest inclination, 34° 42′; HN, a yet unnamed and unnumbered planet, has the greatest eccentricity, 0·38. The mean distance of Thule is 4·25; the mean distance of Eros is 1·46—very wide departures from the theoretical place of 2·73, as indicated by Wurm (Fig. 5).

The volume of the twelve largest planets (Nos. 1, 2, 3, 4, 7, 9, 10, 15, 16, 22, 29, 349) forms two-thirds of the volume of the whole: and since the tiny planets now being discovered add so little to the volume, it is estimated by Dr. Bauschinger, the director of the Berlin Rechen-Institut, that the entire family—including those still to be discovered—would form a sphere not exceeding 830 miles in diameter, or possibly 200 miles less. If its density were even as great as two-thirds that of the Earth, which is improbable, this would give a mass but one-fortieth of the moon's. Of course, there may be relatively large planets which have gone beyond the orbit of Jupiter, as Eros has come within the orbit of Mars, and owing to their distance from us these planets may not yet have been discovered. But this possibility cannot be taken into account in the estimate of the combined mass.

The asteroid that has justified the whole family against Mr. Proctor's plea for indifference to them is one of the smallest—

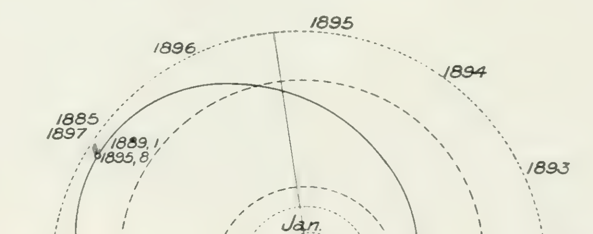


FIG. 5.—ORBIT OF COMET HOLMES COMPARED WITH THE ORBITS OF MARS, JUPITER, THULE, AND MEDUSA.

Eros — in provisional designation DQ, in permanent number 433. This is only from 15 to 20 miles in diameter, and has a surface area of but 700 to 1,250

square miles, even if it be spherical, and there is great reason to think that it is not. It was discovered photographically by M. Witt, of the Urania Observatory, at Berlin, in 1898. But its perihelion distance is only 105,000,000 miles, well within the orbit of Mars, and when at its least possible distance from the Earth it comes within 13,000,000 miles of us, or nearer than any planetary body except the Moon (Fig. 7). At such a close approach it offers the opportunity of a far more precise determination of the solar parallax than by any other method known. Unfortunately, these near oppositions are few—one occurred in 1894, before the planet's discovery, and the next will not occur until 1931. Eros came into fair position in the winter of 1900–1, and many photographs and visual observations were then taken that, when reduced, should give a close approximation to the value of this most desired of all astronomical constants.

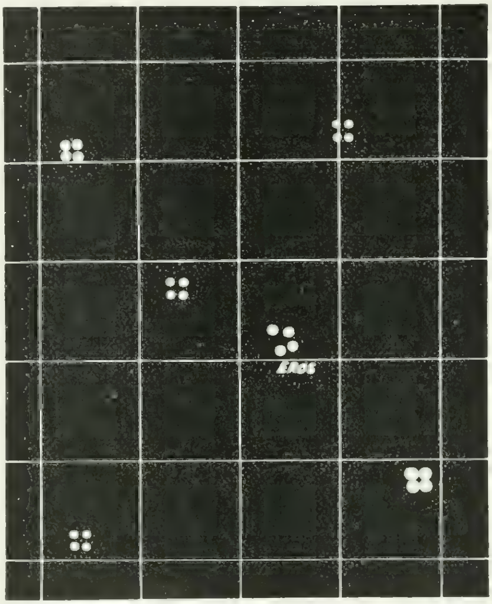


FIG. 6. — PORTION OF A PHOTOGRAPH SHOWING EROS AND THE NEIGHBOURING STARS.

Fig. 6 represents a portion of a photographic plate which has been exposed upon Eros and some neighbouring stars. Before its exposure in the telescope a reticule of lines was printed on the photographic plate, dividing its surface into squares, the sides of which are five millimetres in length. Four exposures were then given to the plate, and the telescope was moved slightly between each exposure. Each star is therefore represented upon the plate by four dots, which are very nearly at the four corners of a small square. But as Eros was moving, with respect to the stars, between the exposures, the four images of Eros make a different figure from the star images, and the planet therefore identifies itself at a glance. Such a plate enables the position of the planet at the four times of exposure to be ascertained with much precision, as its distance can be measured from each and all of the stars on the plate.

Like many other planetoids, Eros displays inexplicable variations in brightness. In February, 1901, the variation was more than a magnitude, and M. Ch. André considered that the period of variability was about $5\frac{1}{4}$ hours. Three theories, which have some bearing on the origin of minor planets in general, have been proposed to account for its changes in light. One is that Eros really consists of two smaller bodies in close contact, revolving round each other, and mutually eclipsing each other. The second is that its shape is that of a dumb-bell, and that the minimum of brightness occurs when the bell shape is end-on to the earth. The third theory suggests as the cause that various parts of the little body have very different reflecting powers. This last theory is largely discountenanced by the fact that the variations in brightness diminished after February and had altogether ceased by May, 1901 ; but it is supported, on the other hand, by the fact that Vesta, by far

the brightest of the planets, is nevertheless considerably smaller than either Ceres or Pallas, all three having measurable discs. This can only mean that the surface of which Vesta is composed has very much greater reflecting power than either of the other two, and no explanation of the cause of this can yet be offered. Indeed, the *albedo*, or reflecting power, of Vesta is quite inexplicably great, being almost as great as that of writing-paper or newly fallen snow. And by all the laws of minor planetary constitution we are forbidden to suppose that Vesta is covered by either one or the other.

The binary or dumb-bell nature of the little planet may or may not receive some confirmation from the strange appearance and behaviour of a comet discovered by Mr. Edwin Holmes in 1892. This comet lay well within the asteroidal zone, its mean distance being 3·8 less than Thule and several other asteroids. Its period of 2,480 days was also less than many asteroids, the inclination of its orbit to the plane of the equator was 20°, much less than that of Pallas; its eccentricity of orbit was 0·39, very nearly that of HN; its perihelion distance 2·17, less than those of several minor planets (Fig. 5). It showed during its course very remarkable variations in brightness, so that it was suggested that it owed its origin to the collision of two of the minor planets, which had both been near their intersecting points at the same time. If Holmes' Comet owed its origin to a collision between two asteroids, it may well be that Eros is formed by the union of a pair into a close double revolving round each other.

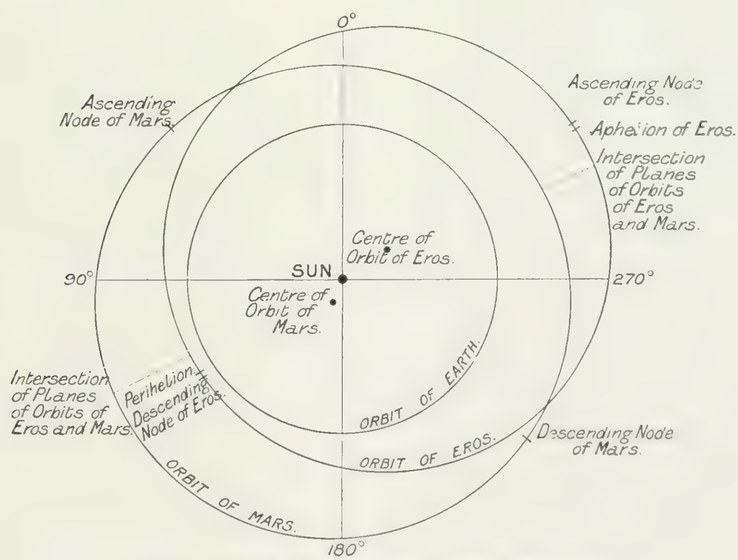


FIG. 7.—ORBITS OF THE EARTH, EROS, AND MARS.

PEARLS AND MOTHER-O'-PEARL.

By WILFRED MARK WEBB, F.L.S.

(Member of the Conchological and Malacological Societies.)

We may well begin this survey of a subject—which in some aspect or other must appeal to everyone—by a consideration of the mollusc.

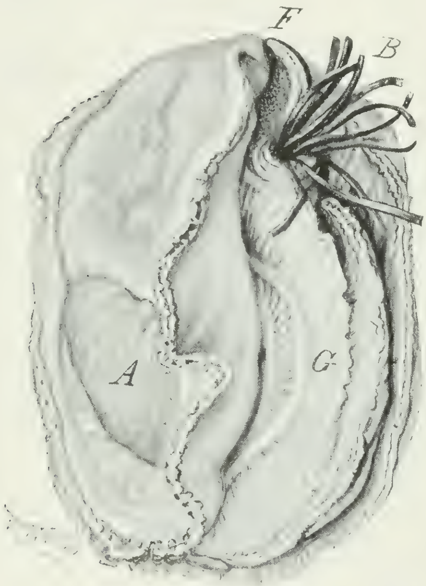


FIG. 1.—THE CEYLON PEARL OYSTER (*MARGARITIFERA VULGARIS*), REMOVED FROM THE SHELL.

A, adductor muscle; B, attachment threads or "byssus." The mantle is thrown back at one side, revealing the "foot" (F), and "gills" (G).

As a matter of fact, the softer parts of the animal stand in a position of nearer relationship to the pearl than its reputed mother, the *nacreous* matter; and, although some may be surprised at the statement, the shells are by far the most valuable product of many "fisheries."

Just as the ordinary oyster starts out into the world as a free swimming creature,* so the pearl "oyster" enters upon an active life which, indeed, it never entirely abandons. Being more nearly related to the sea mussel, the jewel-producer, when attachment does take place, anchors itself by horny threads known collectively as a *byssus*, and secreted by a special gland in the "foot" (Fig. 1). Such cords are familiar even to the less observant among us who have seen common mussels hanging in clusters to one another, and fixed to rocks or piles at the seaside. The silky character of some byssal threads is well illustrated by the fact that in the allied fan-mussels (*Pinna*), which are of large size (Fig. 2), the attachment fibres are capable of being spun, and woven into such articles as gloves.

The pearl "oysters," or mussels, as some prefer to call them, belong to the family *Aviculidæ*, and comprise several species of the genus *Margaritifera*. They are, roughly speaking, circular in outline, and, like the true oysters, have but one large muscle—the "posterior adductor"—with which to close the shell, though in some members of the same family the "anterior adductor" persists as a vestige. In the illustration (Fig. 4) the great "scar" or muscle impression is very evident near the centre of the valve.

FIG. 2.—A FAN-MUSSEL (*PINNA*), WITH WELL-DEVELOPED "BYSSUS."

* See CASSELL'S POPULAR SCIENCE, Vol. I., p. 12.

FIG. .—PEARL DIVERS AT WORK.

Some of the men are using modern diving apparatus, and they are provided with electric lamps. The divers are [illegible] the scrapers employed to detach the shells from their resting place.

The gills and the other main features of the pearl "oyster's" anatomy are so similar to those of the ordinary oyster

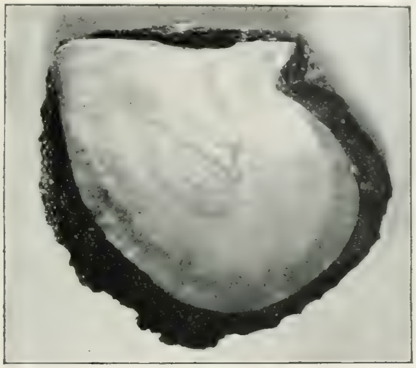


FIG. 4.—LARGE WHITE PEARL OYSTER (*MARGARITIFERA MAXIMA*).

This shell retains much of the edge, which is not pearly, and is usually removed prior to exportation.

that they need not be described here. The shell owes its ornamental and commercial value to the lustre and to the thickness of its innermost component. This, as usual, consists of *nacre*, and there are so many layers of this that the pearly matter forms by far the greater bulk of the valves. In many familiar shells of bivalves and of univalves the "nacreous

FIG. 5.—THE TAHITI BLACK-LIP—A VARIETY OF *M. MARGARITIFERA*.

layers" have only a porcellanous appearance, and lack the peculiar structure which, by refracting or otherwise disturbing the waves of light which fall upon them, gives the unique sheen to mother-o'-pearl.

The large, flat shells which are found on the coasts of Australia, New Guinea, Borneo, the Philippine Islands, and in the Sulu seas, have been recently differentiated by Dr. Lyster Jameson, under the name of *Margaritifera maxima.* These shells are often very massive, and, consequently, are much in demand for manufacturing purposes where the greatest possible thickness of pearly matter is required.

In Queensland the headquarters of the "pearl shelling industry" is Thursday

FIG. 6.—A MODERN "PILGRIM SHELL."

This was carved at Bethlehem from a shell of the pearl oyster of the Red Sea, which is known commercially as "Egyptian."

Island, in Torres Straits, where some 350 boats and over 2,000 men are engaged in the work. One of the most interesting features of the fishery is the truly wonderful number of different nationalities which take part in it. On Thursday Island one may find, to begin with, representatives of nearly every European or Asiatic country; then come Philippine Islanders, Pacific Islanders, and Javanese and Malays. The Japanese are numerous; negroes from Africa and negroes from America have also taken up their quarters there,

not to mention Creoles from Mauritius, Arabs, and Maltese.

Strange as it may seem, in the midst of this most curious mixture very fair order is maintained. The Japanese make the best divers—that is, of course, with the modern mechanical appliances. So well do the Japanese succeed, and so many of them are there, that an alarm has been raised

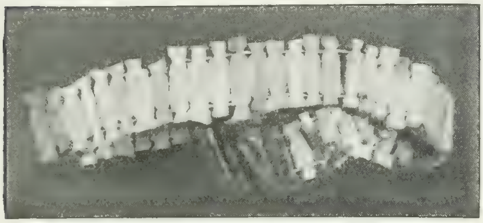


FIG. 7.—A ROUGHLY CUT NECKLACE OF PEARL.

This was made at Bethlehem about the middle of the last century.

lest they should practically take the industry of pearl shelling out of the hands of British subjects in Thursday Island.

Until recently the most profound ignorance with regard to the habits and life history of the pearl oyster existed. In fact, it may be said after a perusal of the evidence given before a commission at Thursday Island in 1897, that nothing at all was known upon most points, and what was adduced or regarded to be best consisted of opinion rather than knowledge based upon experience. The absence of information for a long time, no doubt, prevented the cultivation of the pearl oyster from being seriously undertaken.

Of the shells, 1,085 tons were exported from Queensland in 1896, and in 1900 the quantity was 1,250 tons. Nearly all come to London. A glance at the reports of "M.-o'-P." sales, as they are called, will reveal a number of noteworthy details.

First of all, one finds that there is a decided tendency for mother-o'-pearl shell to become more valuable as time goes on, and it will not be amiss to indicate the methods of describing "quality" which are in use. "Bold" is the term applied to the most desirable shells, the word being often qualified by the addition of such adjectives as "good," "fine," or "heavy." Then come medium, ordinary, or fair, and "chicken" or small shells. Inferior samples are characterised as "grubby" and "pickings," which may be "wormy" or "blistered." "Pieces" necessarily differ in quality and value, while shells which are "dead and stale" are, as may be imagined, the worst of all.

The packages of "M.-o'-P." are counted as they arrive, but as their weight is not recorded, no definite estimate of the quantity imported into this country can be given. The highest price obtained in 1902, according to Messrs. Devitt and Co.'s report, was for Queensland shells, to wit, £15 5s. per cwt. The record price so far is £16 per cwt., and it has been obtained in 1903. In the year 1900 twelve guineas per cwt. was the top price, while thirty or forty years ago mother-o'-pearl was only worth three or four pounds per cwt.

The statement that pearls are often matters of secondary consideration to the pearler will now be easily understood; it is the shell which he is after in many places, though if he comes across a pearl, so much the better for him.

The examples of the same fine species (*M. maxima*) (Fig. 4) from Western Australia bring in nearly the same prices as those just mentioned. Pearling is little known in the south and more thickly populated districts of the colony. The trade, as is the case with that of Thursday Island, is directly with London, which is practically the only distributing market.

In the days of the early settlers, pearling was carried on as an adjunct to pastoral pursuits, but now it has become an industry to itself. The headquarters of the fishing fleet are at Broome. Several luggers of from 10 to 15 tons accompany

PEARL OYSTERS AND PEARLS.

From "Pearls and Pearling Life," by permission of Messrs. Streeter & Co., Ltd.

1 ONE VALVE OF PEARL OYSTER, WITH A PEARL. 2. THE PEARL MUSSEL, WITH A PEARL ATTACHED TO ONE VALVE. 3. PINK PEARL ON *TURBINELLA*. 4 BLACK PEARL IN THE HAMMER OYSTER 5. BLACK PEARL ON *PINNA*. 6. PINK PEARL ON A CONCH SHELL.

each of the schooners, of which there are some seventeen, varying from 60 to 150 tons burden. Diving is carried on, with mechanical aids, from the smaller vessels, and the shells are transferred to the schooners. On board each of these is the owner or his deputy, who superintends the opening of the "oysters," the extraction of any pearls, and the subsequent cleaning and packing of the shells for export. The latter reach England by way of Singapore.

Nearly a thousand hands are employed at Broome, and they consist chiefly of Malays, Manillamen, and Japanese. The last, as before pointed out, are in demand as divers, and they earn £2 a month, with a "lay," or a bonus of £20 per ton of shell raised, so that their wages average about £5 a week. Most of the deaths not caused by accidents are due to paralysis, and the robust constitutions of the Japanese are best able to withstand the strain. Each diver has a "tender" at £4 a month, while the members of the crew, who are chiefly Malays, get £2 10s. for the same period. A lugger costs from £350 to

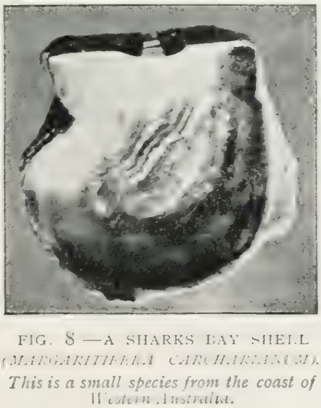


FIG. 8.—A SHARKS BAY SHELL (*MARGARITIFERA CARCHARIARUM*). *This is a small species from the coast of Western Australia.*

£400, and two diving dresses, with the necessary apparatus, another £150.

The season for "fishing" lasts from April to December, when it is put an end to by the cyclones known as "Willy Willies."

Margaritifera maxima is found at low water mark, and is obtained up to a depth of twenty fathoms. Although the shells are plentiful in deeper water, diving is too

FIG. 9.—A CEYLON PEARL OYSTER (*MARGARITIFERA VULGARIS*) WITH A PEARL ATTACHED TO ITS LOWER VALVE.

dangerous to be carried on. Even now the limit of fishing in Western Australia is sometimes fifteen or twenty miles from the shore. Near the Monte Bello Islands the "oyster" shells are of abnormal size and thickness.

The same species is also exported from Port Darwin, and the shell from there is recognised commercially under the name of the locality. Examples from Borneo, the Philippines, and the Sulu seas are termed "Manilla," and one finds "Merqui" shell regularly quoted in the lists.

The high prices obtained for mother-o'-pearl have naturally led to the seeking for new supplies, and to the endeavour to cultivate them scientifically. In this connection Dr. Lyster Jameson spent a year or more in the coral islands known as the Conflict Group, situated between New Guinea and the coast of Australia.

To be considered the best from a commercial point of view, mother-o'-pearl shells must be white, with a "silver lip." A "gold lip" or "yellow edge" is considered a defect, and black edges still further reduce the value, unless ornaments of "smoked" pearl are fashionable, when prices will go up.

"Australian and New Guinea Black-

lip" is the name given to one of the many varieties of the pearl oyster called *Margaritifera margaritifera*, Linné. It was with this species that the flatter shells of *M. maxima* were till recently confounded. The black-edged shells previously mentioned are found in shallow water on coral reefs, and brought up by naked divers, who descend to a depth of five fathoms. Good samples have varied in price of recent years from £3 to £9 10s. per cwt.

FIG. 10.—TWO VALVES OF JAPAN "LINGAH" (*MARGARITIFERA MARTENSII*).

Other kinds which must be passed over are "Fiji" (Fig. 5), "Auckland," and "Tahiti" black-lips. The latter was given a varietal name (variety *Cumingii*) by Reeve. Then there are the "black-edged Banda," "Gambier" (sometimes corrupted to Gambia) from the Society Isles; and "Zanzibar" (variety *zanzibarensis*, Jameson). "Egyptian" (variety *Erythræa*, Jameson) comes from the Red Sea, where it is fished by Arabs without diving-dress. It is this kind which for very many years has found its way into the Holy Land, and furnished material for the so-called "pilgrim shells" (Fig. 6). The villagers at Bethlehem more particularly used to make rough, incised pictures of a religious character upon the valves, and fabricate rude beads and ornaments in pearl (Fig. 7). Now the industry has reached large proportions, and the work turned out is of much greater excellence and variety.

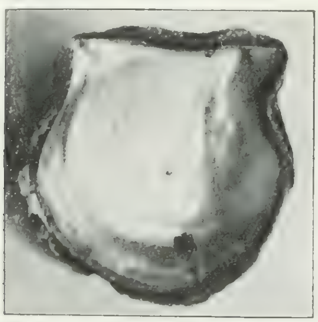


FIG. 11.—THE BOMBAY "LINGAH" FROM THE PERSIAN GULF: LOWER VALVE.

Bombay shell (variety *persica*, Jameson) comes from the Persian Gulf, and the last representative of *Margaritifera margaritifera* is "Panama" (variety *bavata*, Reeve), from the place whence it takes its name on the Pacific coast. "Sharks Bay Shells" (*Margaritifera carcharianum*, Jameson) (Fig. 8), coming from Western Australia, are much smaller and of considerably less commercial importance. In 1902 they were a little cheaper, fetching only from 9s. to 24s. a cwt. By far the largest quantity of the shell goes to Singapore, and is used by the Chinese.

The shells of the Ceylon pearl oyster (*Margaritifera vulgaris*, Schumacher) (Fig. 9) are not used commercially; but, under the name of "Lingah," shells of the same species, coming from the Persian Gulf (Fig. 11), are to be seen at the "M.-o'-P." sales. The convexity of the valves is a great drawback, and 26s. a cwt. seems to be the highest price realised of late years for "Lingah," which is used for making small buttons. The Japanese "Lingah" is *Margaritifera Martensii*, Dunke (Fig. 10). The West Indian pearl oyster is *M. radiata*, of Leach, and occurs off Texas and Venezuela, among other places. Lastly, there is the species *M. lentiginosa*, of Reeve, known as "White Banda shell," from the Philippine Islands (Fig. 13).

We may now turn to the general uses

of mother-o'-pearl, at the same time mentioning the other specially endowed shells, bivalve and univalve, which are used in the "arts." It will hardly be necessary to go into much detail. The most obvious use to which the material under consideration is put is in the manufacture of buttons. Discs are cut out from the shell (Fig. 12) with an annular saw—a hollow tube with teeth on the end—fixed into a lathe head. If the shell is thick, the discs may be split into two or more; afterwards they are ground and turned. A pattern may be next cut upon their face, and, after being drilled, they are polished.

As has been indicated previously,

FIG. 12.—A MOTHER-O'-PEARL SHELL FROM WHICH PIECES HAVE BEEN CUT FOR BUTTONS

"smoked pearl" buttons are made from black-edged shells; others may be cut from the handsome "Japan ear" shell (Fig. 14). This is a univalve—a foreign representative of the genus *Haliotis*, to which the "ormer" of the Channel Islands belongs.

The "mussel" of the "M.-o'-P." trade is *Pteria macroptera*, from the Persian Gulf, and a variety, less valuable owing to the nacre having a bronze hue, comes apparently from Australia.

Fresh-water, or, in trade parlance, "sweet-water" mussels (of the genus *Unio*) from America, sometimes appear

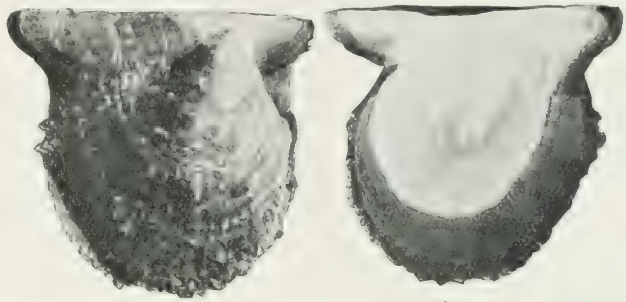


FIG. 13.—"WHITE BANDA SHELLS" FROM THE PHILIPPINES.
a, *external*: *b*, *internal view*.

in the catalogues. In the United States (Iowa) a number of factories exist where fresh-water mussel-shells are used. A factory with ten saws will turn out from 800 to 1,000 gross of buttons per week. Buttons, sixteen lines across, fetch 48 cents a gross; of twenty-three line samples, 70 cents. per gross, if of the first quality. So great is the demand for the mussel shells that steam dredges have been set to work in the rivers, and the supply of mussels (if some means is not taken of maintaining and increasing it) will before long become exhausted. Enormous quantities of shells are wasted by

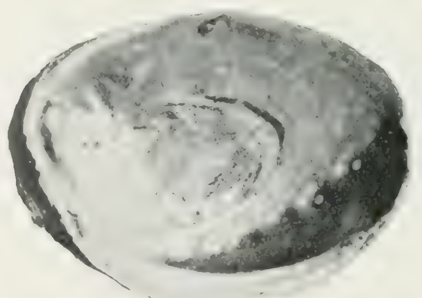


FIG. 14.—"JAPAN EAR" SHELL
(*HALIOTIS GIGANTEA*).

those who seek for fresh-water pearls in districts where no factories exist. In Europe purses have for long been made of the polished valves of fresh-water

mussels hinged together. After buttons come sleeve links, solitaires, and studs. "Green Ear" is used to cover the tops of solitaires. The handles of pocket-knives and, still more, dessert knives and forks, run away with much mother-o'-pearl; the solid pieces necessary for the last two have to be cut from the thickest parts of expensive shells, and only quite recently the Sheffield makers have advanced their prices 15 per cent.

Another shell which is regularly quoted in the trade lists is "green snail" (Fig. 15), a species of Turbo (*Turbo olearius*), coming from Singapore and New Guinea; it is turned into buttons, or used for "fancy" purposes.

When one attempts to explain the formation of pearls, it is well to begin by making clear the way in which the shell of the ordinary bivalve mollusc is thickened and enlarged. The prolongations of the body wall, which are known as *mantle flaps*, closely approximate to the margin of the shell in the normal condition, and can be protruded, when the shell is to be enlarged in area, to its very edge. It is

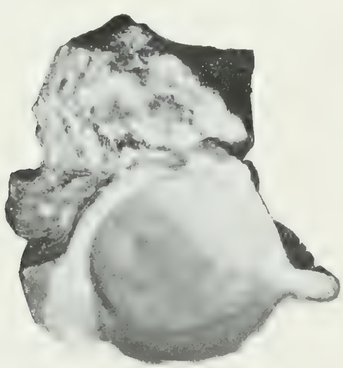


FIG. 15.—"GREEN SNAIL"
(TURBO OLEARIUS).

the boundary of the mantle which secretes the *periostracum*, or layer of animal matter that, unless destroyed, covers the outside of the molluscan shell. The limy and organic material which forms the *crystalline calcareous layer* that in the pearl oyster, as in other shells, comes next, is poured out also by glands at the edge of the mantle. The surface of the latter, however, which comes into contact with the whole of the interior of the valves,

FIG. 16.—THE GREAT CONCH
(STROMBUS GIGAS).
Pieces of this shell are worked in with mother-o'-pearl for making studs.

produces one after another the manifold *nacreous layers* which make up the third component of the shell. This is what in certain cases goes by the name of mother-o'-pearl.

A pearl itself, apart from its nucleus, is entirely made up of precisely similar nacreous matter, secreted, owing to some exciting cause, in greater abundance or in an unusual position. Sir Edwin Arnold has summed up the ideas which are generally held in this connection when he tells us that the oyster "gems his shallow moonlit chalice," and

> "Where the shell irks him or the sea sand frets,
> There from some subtle organ he does shed
> His lovely lustre on his grief and gets
> Peace, and the world his labour, being dead."

This is correct enough, so far as it goes, in the case of foreign objects (Figs. 17, 18, and 19), which are coated over and cause projections or "pearl blisters" on the internal surface of the shell; but this does not appear to be the only explanation of the formation of true, free pearls, which are found embedded in the substance of the mollusc, and of those which, having once occupied such a position, have afterwards become attached to

the shell (Fig. 9). The most recent contribution to this very interesting subject is based upon the pearls found in large numbers in the common mussel (*Mytilus edulis*). The nacreous layer of the shell in this species is not pearly, and the pearls are necessarily of no use as jewels; they proved, however, exceedingly useful, in the absence of other material, to Dr. Lyster Jameson. This investigator discovered that the pearls of *Mytilus* are due to one of the stages in the life-history of a fluke, a parasitic flat-worm (*Distoma*). The tailless cercarian larva of the latter takes up its position under the skin of the mussel's body, and there becomes surrounded by an epidermal sac similar in character to the shell-secreting *epithelium* of the mantle. If the parasite dies it becomes calcified, and forms the nucleus of a pearl. The *cercariæ* sometimes migrate from the sac, and the *débris* they leave behind, in a similar way, supplies the necessary centre round which a pearl is built up. Dr. Jameson found the remains of parasites in numbers of the pearls which he examined. The early life of the fluke is passed in another host (also a mollusc), being either the common cockle (*Cardium edule*) or *Tapes decussata*.

FIG. 17.—A CRAB WHICH HAS GIVEN RISE TO A PEARL BLISTER.

From a specimen in the British Museum.

FIG. 18.—A SHELL WHICH HAS CAUSED A PEARL "BLISTER."

FIG. 19.—SHELL CONTAINING A FISH COATED WITH MOTHER-O'-PEARL.

From a specimen in the British Museum.

It is evident that such a pearl as we have described will be separated from the shell and be embedded in the flesh of the

FIG. 20.—A CHINESE FRESH-WATER MUSSEL (*DIPSAS PLICATA*) WITH PEARL-COVERED JOSSES.

mussel, just as the valuable spherical or pear-shaped jewels of the pearl oyster are found to exist.

The theory that parasites gave rise to pearls in pearl oysters was brought forward more than forty years ago, and Mr. Edgar Thurston, superintendent of Madras Museum, figured the larvæ of flat worms in the Ceylon species, saying that "it is not improbable that these minute parasites may form in the tissues loci favourable to the laying down of layer after layer of nacreous deposit."

FIG. 21.—SECTION OF A TRUE PEARL, *i.e.* ONE FORMED NATURALLY. FROM THE COMMON MUSSEL (*MYTILUS EDULIS*). (*After Lyster Jameson.*)

Mr. Stephen Pace, when discussing pearls at a meeting of the Malacological Society some years ago, objected to the "sand-grain" theory, because pearls occur where sand-grains could not reach, and because no sand-grains are found in pearls. The nuclei, according to this observer, are crystalline, and devoid of animal matter. They may be found in the blood and renal organ (particularly), sometimes with the beginnings of the nacre creeping over them; and their presence is due, Mr. Pace contends, to a pathological condition of the pearl oyster. That the state of body is communicable, Mr. Pace demonstrated to his own satisfaction, for he obtained, experimentally, in what were healthy oysters to begin with, 4-grain pearls after the expiration of nine months. It is quite possible that pearls might be formed in both of the ways indicated, and in others as well. The artificial production of real pearls on a large scale seems only a matter of further experiment.

Dr. Jameson recognised the occurrence of concretions, but is of opinion that not being enclosed in epidermal sacs, they cannot acquire the structure of shell substance—that is, become pearls. In some cases he traced their origin to dead parasites. A very different kind of structure is the "hinge pearl," formed of material like the ligament joining the valves. These in the pearl oyster are sometimes several inches across.

It may not be amiss to consider for a moment the ancient explanation of the origin of those jewels which need no such artificial aids as cutting and polishing to add to their beauty. According to Oriental poets, on a certain day in each year

oysters rise to the surface of the water and open their shells to receive the drops of rain which Buddha showers upon the earth. Others claim that the oyster in similar fashion drinks the dew, and Pliny says that according to the quality of this the pearls do vary. Shakespeare touches upon the idea when he makes Richard III. say:

> "The liquid drops of tears that you have shed
> Shall come again transformed to Orient pearl,
> Advantaging their loan with interest
> Of ten times double gain of happiness."

While we are upon the subject of the strange ideas which have existed, the belief that pearls increase and multiply, or both, after they have been removed from the shell deserves a passing consideration. The jewels must be put away in rice—red rice by preference—and they will, it has been claimed, grow larger, and produce bulges on their sides, while in one recorded case a dozen pearls, after having been left for ten or twelve years, were found to have increased to "hundreds," so the story goes!

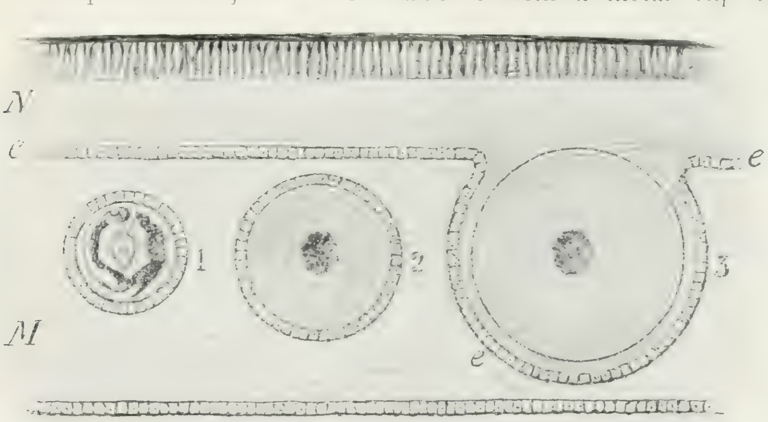


FIG. 22.—DIAGRAM SHOWING A SECTION THROUGH THE SHELL AND MANTLE OF A MUSSEL. *(Modified from Jameson.)*

M, mantle; N, nacreous layer; e, epithelium; 1, Larval fluke embedded in the mantle, and surrounded by an epithelial sac; 2, a pearl formed in a similar sac; 3, a pearl which has forced its way out of the mantle and become attached to the shell.

Turning now to the actual pearl fisheries, it may be said that those in India were famous in very early times. Friar Jordanus, who visited the country about the year 1330, says that 8,000 boats were then engaged in the pearl fisheries of Tinnevelly and Ceylon.

At Tuticorin fishing begins in February, and the firing of a gun about midnight is the signal for the native boats, with their divers, to set off. On arrival at the banks, the naked divers sink themselves by means of a stone weighing some thitry pounds (Fig. 26), placing a foot upon it, and grasping with the left hand the rope to which it is attached. The diver closes his nostrils with his right hand or with a metal clip suspended round his neck with a string. A basket or net is attached to another rope, and when the diver reaches the bottom he sets about filling this, and is drawn up with it, his stone having previously been pulled into the boat. The time spent below the surface is usually about fifty seconds, but some men stay down for even ninety seconds.

Each diver sends up some 2,000 oysters a day, operations ceasing about noon. When the shore is reached, each set of divers divides their oysters into three heaps; one of these, chosen by a Government official, becomes their property.

On the small scale, oysters are opened with a knife, but usually the shells are left

until the animal matter decays or is got rid of with the help of big, red-eyed blue-bottles. An invasion of cholera will, of

FIG. 23.—A SECTION THROUGH A PEARL OYSTER.
(Much enlarged. After E. Thurston).
P, P, parasite.

course, upset the whole arrangement. For instance, once when Mr. Edgar Thurston visited the Ceylon fishery, the whole camp was burned down and the fleet and the boat crews disappeared within a few hours of the first deaths from cholera taking place.

Sharks may also cause a panic, which can only be removed by a shark charmer,

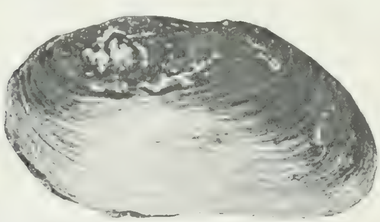


FIG. 24.—THE BRITISH FRESH-WATER PEARL MUSSEL *(UNIO MARGARITIFERA)*: EXTERNAL VIEW.
This is the species that produces the "Scotch" pearl.

whose office is hereditary, and who performs some mystic ceremony.

It is hardly necessary to go very deeply into the value of pearls. Just now irregular growths, more of the character of blisters, and called "Baroque," put into quaint settings, are rather fashionable; but, of course, by no means so costly as choice jewels. The price of a necklace of forty-five pearls recently exhibited at the Paris Exhibition was £90,000. In such a case the time and trouble spent in matching the individual pearls are taken into consideration. A specimen the size of a marble, found in shallow water by Mr. Henry Haynes in the Queensland fisheries, was valued at £950. Historical pearls of large size have been sold for many thousands of pounds.

As the colour of the nacreous layer in the pearl oyster varies, so does that of the pearls; in addition, therefore, to the brilliant white ones, which are most esteemed, there are found pink, yellow, and smoky specimens. Pink pearls are produced by univalves, such as the conch (*Strombus gigas*). Some excellent pearls have been obtained from the pearl

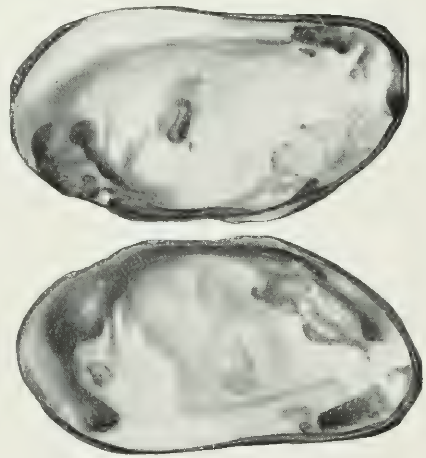


FIG. 25.—*UNIO MARGARITIFERA*: INTERNAL VIEW.

mussel (*Unio margaritifera*) (Figs. 24 and 25) of British rivers, and these, though the species is by no means confined to the north of the Tweed, are often known as "Scotch" pearls.

British pearls were well known to the Romans, and there seems to be little doubt that Julius Cæsar had them in mind when he came to these shores.

The prehistoric dwellers in North America used to collect pearls from the many species of *Unio* which have lustrous interiors, and of recent years "pearl fevers" have broken out in one place or another in the United States, only to subside again when the mussel beds have been exhausted.

(The writer wishes to express thanks to Sir Horace Tozer, Mr. Lefroy, Mr. Hansen, and Mr. van Noorden for much valuable help.)

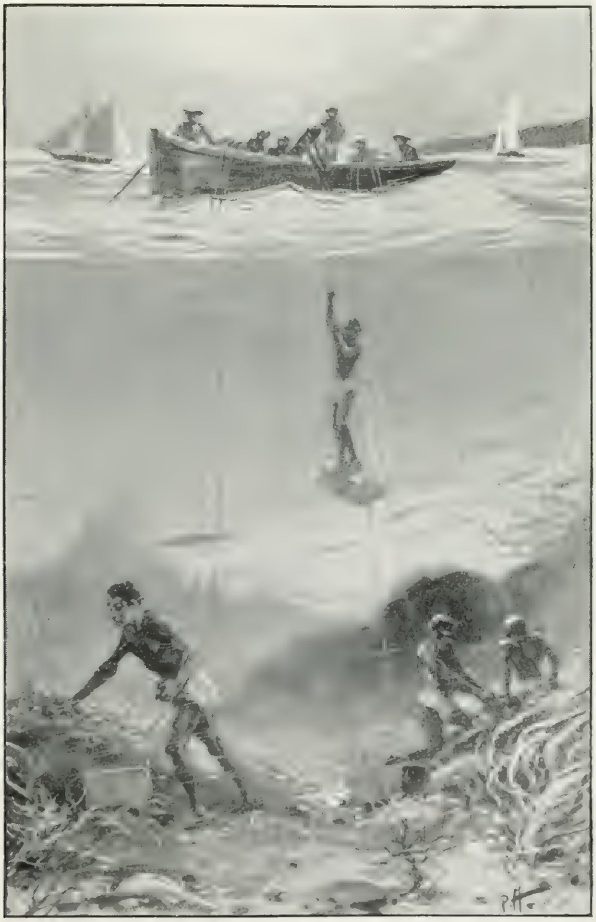


FIG. 26.—DIVING WITHOUT THE AID OF APPARATUS.

Notice the heavy stone, or sinker, which rapidly carries the diver to the bottom.

NERVES AND NERVELESSNESS.

By Dr. ANDREW WILSON, F.R.S.E., F.L.S., etc.

Formerly Lecturer on Zoology in the Edinburgh School of Medicine, and Examiner in Natural History and Botany in the University of Glasgow.

LIKE many other curious functions of our bodies, the art of feeling and of exercising sensation loses its wonder, and ceases to interest us, because of its common nature. It is, however, the special gift of science to show the wonders which exist within the most limited field of observation and in the most common objects which surround us. Within the confines of the human body there are exemplified, it is true, problems of matter and of mind which the farthest flights of scientific philosophy have as yet failed to explain. But it is equally true that there are many points in our own history and daily life which this same philosophy has fully elucidated, and which have been shown, notwithstanding their familiarity, to present elements of great interest and of sound instruction.

Of such familiar points, the ordinary course of nerve-action and sensation are good examples. No fact in our personal history is clearer than that which shows, as the result of experience, that we are able to gain a certain amount of knowledge of the world around us. To this knowledge we are enabled to attain through the exercise of our "senses"; and our "senses"—whatever these may prove to be—are known in their turn to be parts of our nervous system. In each act of our daily life, no matter how trivial, or how oft-repeated the act may be, the nervous system plays a part. The very beating of the heart—carried on involuntarily and unconsciously, as in sleep—the winking of an eyelid, and the thinking a thought, are actions each and all carried out under the supervision of and controlled by the nervous system. Thus we discover that this system is that whereby we are brought "into relation" with the world around us. The higher the nervous system, the more perfect is the relationship which it maintains between its possessor and the outer universe. And hence for all purposes of scientific definition, as well as to popularly designate the use of the nervous system, we may say that it performs the "*function of relation*," and brings its possessor into contact with the surrounding world.

It is an obvious conclusion, however, that the manner in which the functions of nerves are exercised is seen to be subject to striking variations as we survey the wide domain of animal life, and include in our glance the lowly animalcule, and the "lord of creation"—man himself. The acts of an animalcule are simple indeed, as compared with the complex actions which mark the daily life of man; and still greater do the differences appear which seem to separate the apparently non-sensitive plant from its sensitive animal neighbour. But the physiologist might after all show that the differences between most of the nervous actions of man and those of lower animals are more apparent than real. And he might go farther still, and assert that the plant-world should not and may not be left outside the category of sensitive things of nature. He would endeavour to show that there exist plain grounds for the belief that sensation is not confined to the animal world, and that plants may "feel," and may act upon their feelings and sensations, as do animals; whilst, more extraordinary still, the man of science might inform us that the presence of nerves was not a necessary condition for the due exercise of sensation; and that, in short,

many animals and plants "feel," in the entire absence of nerves. Hence it would seem that the common "art of feeling" constitutes, after all, a most singular phase in the history of living beings; and this brief investigation of the subject may, therefore, help us to find an answer to the many interesting questions which are connected with it.

A brief study of the features involved in the common exercise of the nervous system in man may fitly preface a wider glance at the subject of the relations of nerves and nerve-action in living beings at large. When we touch a table, for instance, what features are involved in the action, and how is the act itself inaugurated and carried out? Starting with the assumption that the action has originated in a "thought" or "idea" generated in the brain—for there are some philosophers who would maintain that this thought is but the outcome and product of antecedent thought or nerve-action—we find that the "idea" gives origin to "nerve-force" or "nerve-impulse." What this "nerve-force" is we cannot tell; neither has it been made plain how a thought becomes transformed into the force which has the power of calling our muscles into play, and, it may be, of exciting the most violent bodily action. Somehow or other, however, the idea is so

[illegible]

FIG. I.—THE TELEGRAPH PLANT *(DESMODIUM GYRANS).*

The leaves of this curious plant are scarcely ever still. They describe almost complete [illegible] Specimens of this plant may be seen growing during the summer in the Wat[illegible] House at Kew.

transformed; and, stranger still, it is actually directed and guided, as if by the hand of a skilful pointsman, into the particular channel or nerve we desire. If we wish to employ the fore-finger in touching the table, the nerve force is directed through the appropriate nerves to this particular member. If the middle finger is the desired member, the nerve-force will affect it—right hand or left, one finger or all the fingers, it matters not which to the brain-pointsman—the nerve-force is

directed unerringly to the particular portion of our frame we desire to affect. Thus, one of the most familiar acts and powers of our daily life—the power to do as we choose, to lift this finger or that—is really performed through a mechanism so subtle and incomprehensible that the greatest authorities of our day own their inability to solve its depths, and admit their helplessness with the best grace possible.

Through the nerves, then, flows this wonder-force, of which, indeed, "thought" itself is but a modification. Flashing down the arm and finger, it intrudes itself upon the muscles thereof. Rousing them from their state of rest, it calls upon them

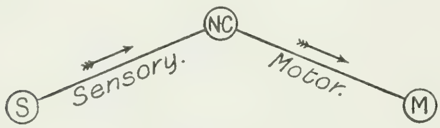


FIG. 2.—HOW IMPRESSIONS ARE CONVEYED TO AND FROM THE BRAIN.

to contract, and, like a stern taskmaster that brooks no opposition, insists on the instant execution of its commands. The willing muscles obey ; the arm and finger are duly moved, and the latter member is brought into contact with the table. The desired action has thus been accomplished, you say, through the transformation of thought or brain-force into nerve-force, through the transmission of this force to the muscles, and through the subsequent stimulation, contraction, and movement of these latter structures. So far, the steps of the action are clear enough. But this is not all. The details just given literally involve only one-half of the action of touching the table. How do you know you have touched the object in question? You reply, "Because I see I have touched the table, and because I feel I have touched it." Just so ; but "feeling" and "seeing" are both nervous acts, involving actions as complicated as those through which you set your muscles to work. Suppose, for the sake of clearness, that a blind man touches the table. His knowledge of that part of the outer world represented by the table is gained by one sense only—that of touch. How does he know he has touched the table ? Again you reply, "Because he felt it." And what is feeling, and how does he feel ? To answer these queries we must try to understand what these "senses" of ours are, and what the possession of a "sense"—such as that of touch—implies. Professor George Wilson long ago called the senses the "gateways of knowledge," and the term is an exceedingly appropriate one. For through these five or six gateways comes information upon all manner of subjects—"information received," in fact, and upon which, like sagacious policemen, we are bound to act.

Now "touch" is of all the senses the most diffused, and of all our knowledge-gateways the widest. A little cogitation makes it clear that the sense of touch—that is, the sensation produced by our contact with the table—is not confined to the nerves situated in the skin of the finger. And a little further thought will result in the idea that before we can "know" anything about the table, the brain must have been duly informed of what is going on at the tip of the finger. In the blind man the gateway of the eye is closed, and it is therefore through the finger and the sense of touch alone that the information can be conveyed to his brain. How, then, is this very necessary communication effected ? The nerves supplying the finger, and, indeed, all the ordinary nerves of the body, are composed of two kinds of fibres, named *motor* and *sensory fibres*, respectively. These fibres are indistinguishable as they exist in a nerve, although, at the point where the nerves leave the spinal marrow, these two kinds of fibres are separate and distinct, and exist as the "anterior" and "posterior roots" of the main nervous trunks. The functions of the two varieties of fibres are widely different. Through the one set, named *motor fibres*, impulses flash *outwards*, or *from* the brain *to* the muscles. Through

the other set—the *sensory fibres*—impulses are conveyed *inwards*, *from* the outer parts of the body, and *from* its muscles to the *brain* or other chief centre of the nervous system. Thus, then, it becomes clear to us that, when we wished to touch the table, the nerve-impulses which set our muscles in *motion* passed from the brain through the *motor* fibres of our nerves; and that, conversely, we became aware that we had touched the table, because the *sensation* of touch—produced by the contact of the finger with the table—was transmitted to the brain through the other or *sensory* fibres of the nerves. In like manner, if we had seen our finger touch the table, the eye would have then served as a great sensory organ. Hence arises the idea of its exercising a *sense*—seeing that it conveys *to* the brain information regarding the work and functions of the finger and its muscles. Or, supposing that a person passes his hand quickly before our eyes, we withdraw our head and instinctively close the eyelids. Here the sensory impulse has passed (Fig. 2) from the eye (S) to the nerve-centre or brain (NC), and has thence been "reflected" as a motor-impulse to the muscles of neck and eyelids (M). We must, therefore, note that in every nervous action there are two aspects involved. The impulse sent outwards is ultimately *reflected* inwards, and carries with it to the brain the knowledge of what is going on without. This is what physiologists know under the name of *reflex action;* and it can well be understood from the foregoing examples. Most, if not all of, our actions are regulated and performed in conformity with the plain principle of impulses being "reflected" inwards or outwards, as the case may be.

That the impulse which determines the bodily actions does not always originate in the brain is a fact which becomes clear to us when we consider that we are acted upon in various fashions by the outer world, and have in turn, and as the result of the impressions we receive, to react upon the world. Why does the sight of some tit-bit in the way of dainty food cause a flow of saliva, or, in plain language, "make the mouth water"? Because the sensory impulse received by the eye has been transmitted to the brain, and "reflected" therefrom to the nerves of the salivary glands in the mouth, with the result of causing a flow of their secretion, such as would ensue were the savoury morsel to be eaten. A story is related of a distinguished chemist, which illustrates, in a remarkable manner, not merely the theory of "reflex action" just discussed, but also the rapidity with which bodily action may follow the receipt and transference of nervous impressions. The chemist in question was engaged in examining the contents of a phial, when these contents suddenly exploded, and the bottle was dashed from his hand into a thousand fragments. He was conscious of seeing the flash which accompanied the explosion; and in the immeasurably short interval which elapsed between the explosion and the unclosing of his eyelids, came the agonising thought that possibly he was blinded for life. A moment later, on opening his eyelids, he found, to his immense relief, that his eyes were uninjured; but on the outside of his eyelids and in his face were small particles of glass. This latter observation, therefore, showed that, notwithstanding the extreme shortness of the interval which elapsed between the flash of light and the shattering of the glass, his eye had still had time to warn the brain of its danger, through a *sensory* impression; and the brain had also contrived in the interval, and through a *motor* impulse, to issue a command to the muscles of the eyelids to close, and to protect the delicate organs under their care—as illustrated by Fig. 2.

Such is a short account of the essential phases in human nerve-action, and in that of allied animals as well. Reflex action in reality forms the basis, as has been already remarked, of our daily walk and conversation,

and may often be carried on automatically or unconsciously to ourselves, and through the influence of that power of habit which has well been termed a

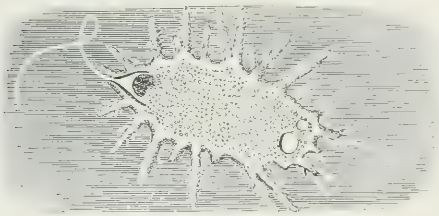


FIG. 3.—*MASTIGAMŒBA ASPERSA.*
(After F. E. Schulze.)
This curious little animal, which is a fresh-water transition-form between the Amœbæ and the Flagellata, is an apparently shapeless mass of living "jelly."

"second nature." The considerations which follow upon the investigation of the manner in which the highest animals maintain relations with the world around them invite us to glance at the nervous acts of lower forms of life, and to compare their actions with those of their higher neighbours. Let us, for instance, select that well-known animalcule the *Amœba*, or "Proteus animalcule," or its ally, portrayed in Fig. 3, as a first object for study. The amœba slowly moves about in a little sea of its own, formed by a drop of water taken from a stagnant ditch—a curious, shapeless speck of living jelly, without organs or parts, and, as we watch it even for a few minutes, seems to flow continually from one form into another. The amœba—this microscopic speck of structureless living matter—is, notwithstanding the simplicity of its body, a veritable animal, that lives to and for itself as completely and as perfectly as does the highest of beings. You see a particle of solid matter approaching the amœba, and now it has just touched the margin of the soft, jelly-like body. The animalcule acts most characteristically; for it proceeds thereafter to enclose the food-particle with its body, and literally flows around the particle, which is seen to be finally engulfed within the soft substance, amidst which, if digestible at all, it will be slowly dissolved. What shall we say of the amœba's act and behaviour to the food-particle? Simply that the animalcule "felt" the contact of its body with the particle, and that it acted—unconsciously, no doubt, but like man nevertheless—upon "information received," and seized upon the substance for food. This appears exceedingly like "reflex action" in a lower phase after all, for here you see an impression received from without, and you also behold action of a definite kind from within to follow the receipt of that impression. We may not dogmatise regarding the nerve-functions, or "irritability," as the nervous sense is termed, of an amœba; but this much we may affirm with safety, that the soft tissue of the structureless and nerveless

FIG. 4.—A MEDUSOID (*CHRYSAORA*).
The "tongue" or "clapper" hangs, as shown, from a dome-like "roof." The rudimentary eyes are placed round the margin of this "dome."

body is sensitive, and that its sensitiveness may be, and is, excited in a general manner by the contact of the outer world and its belongings. We may add that, all living matter being sensitive, the amœba acts and reacts as described because, being composed

of living matter, it possesses inherently the property which we may term "irritability" or nervousness.

The summer sea around our coasts teems with many beings of graceful form and appearance, but with none more beautiful to the eye or interesting to the mind than the "Jelly-fishes" or *Medusæ*, whose curious, glassy bodies are near akin in delicacy to the water amidst which they float, and which drain away in your hand as you attempt to lift them from the sea. Here is one form (Fig. 4) which comes sailing along through the still sea, expanding and contracting its bell-shaped body with a regularity which is both surprising and noteworthy in a being of so lowly a grade. From the roof of the bell hangs a "tongue" or "clapper"; around its margin you may see little specks of pigment, which are *ocelli* or rudimentary eyes; and you may notice tentacles or feelers as well. A sheet of contractile tissue lines the interior of the bell and covers the "tongue." By the contraction of this delicate layer, the walls of the body are drawn together and water is ejected from its mouth, the animal being thus propelled; whilst the subsequent enlargement and dilatation of the bell results in an inflow and an expulsion of water. In this way, by alternately expanding and contracting its body, our medusa pulsates through the water, like a veritable creature of fairy organisation of almost ethereal nature. Let us interrogate the jelly-fish by experiments similar to those carried out by the late Dr. G. J. Romanes, and inquire as to the means it possesses for maintaining relations with the outer world. We must dismiss from our minds, in dealing with the medusa, any idea of "consciousness," or the knowledge of the why and wherefore of our actions which is so characteristic of man. For the lower animals perform the actions of their life under unconscious stimulation from without, and without necessarily knowing or appreciating the reasons of their acts. With a needle or other sharp instrument prick the side of the bell-shaped body of the jelly-fish, seen in Fig. 5, and you will find that the central tongue or clapper of the bell bearing the mouth will move to the irritated point (*a*) just as the indicator of a dial moves in response to the mechanism whose working it is meant to indicate. Prick another part of the bell, and the mouth will move unerringly to the second point you have touched. Such a result shows us clearly, not only that the jelly-fish feels, and that acutely, but that through reflex action it is enabled to respond to the stimuli by the movements of its mouth, and in an accurate

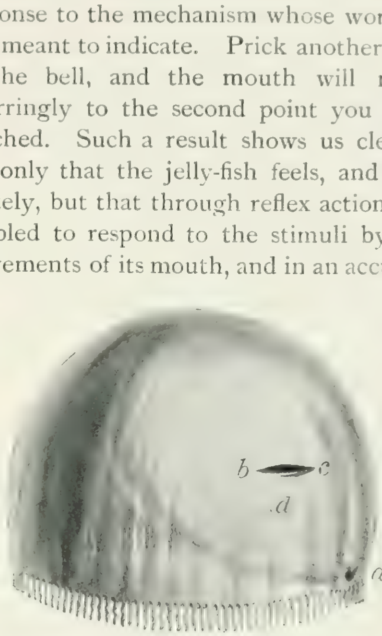


FIG. 5.—A JELLY FISH.

a, the mouth.
b c, shows a cut made in the side.
d, point at which a pin is inserted.

manner to indicate the points which have been touched. In some medusæ, the reason for the movement of the mouth to the point which has been touched is explained when we discover that the mouth is provided with a stinging apparatus, which, by the movements alluded to, would be brought into contact with any foreign object or animal touching the body of the jelly-fish. Suppose that now we make a cross-cut in the side of the jelly-fish (Fig 5, *b c*), and sever the delicate body-substance through a limited part of its extent; and, further, that we prick the body below the incision, as at *d*—that is, on the side of the cut farthest from the mouth. The mouth then moves about in an erratic fashion, as if at a loss to discern the exact point which has been irritated.

The explanation of these facts must be prefaced by the announcement that no very definite nerves are to be discerned in the vast majority of our jelly-fishes. They are thus essentially like the amœba—sensitive in the absence of well-defined nerves, such as are the natural heritage of animals higher in the scale. This fact alone is curious and noteworthy, and bears a distinct relation to certain conclusions to be drawn at the close of our investigation. We may firstly form some idea of the manner in which the medusa contrives to indicate the point of its body which is touched, by assuming that the impressions or sensations are conveyed from the exterior of the body to the central mouth through definite tracts or lines—"lines of discharge," as they are called; and, secondly, that this idea is supported by the experiment just alluded to. When the line along which the nervous impulse travels is interrupted by a cross cut, the information is conveyed to the central mouth in a roundabout fashion, the impulses scattering themselves, as it were, over the body, and in such an incomplete manner that it is unable to indicate as correctly as before the seat of the irritation. In an experiment of Dr. Romanes', the bell of a jelly-fish was cut, as exhibited in Fig. 6, into "a continuous parallelogram," and then divided as shown in the illustration. When any point, such as *a*, in this divided portion was stimulated, a wave of contraction passed to *b*, proving that the "wave of stimulation" must have passed round and round the ends of all the intervening cuts. When the wave reached *b*, near which a nerve-mass or *ganglion* (*g*) is situated, it would be "reflected" from this nerve-centre backwards to *a*. Not only do we find the principle of reflex action thus represented, but we also witness the aptitude of all parts of the medusa's sensitive body to receive and transmit impressions. We find in the jelly-fish, in short, when its tissues are divided, much the same kind of effect that ensues in higher animals, in parts supplied by any special nerve, when that nerve has been divided, or otherwise injured. In such a case impressions would have to be conveyed in a roundabout manner, and in an irregular fashion, to the part in question. We may conclude our survey of the jelly-fish by noting its evidently superior organisation to that of the amœba. The result of this higher structure is shown in the more definite and exact manner in which the impulses are conveyed from outward to inward parts; these impulses in the amœba being undetermined in their direction, and very general in their scope and extent. We have already noted that the principle of reflex action appears to be carried out in the medusa in much the same fashion, as regards its working, as in man himself.

A step upwards in the scale of animal life would bring before us animals in which definite nerves are developed, these nerves merely representing a higher development of the primitive "lines of discharge" along which the nerve-impulses of jelly-fish and amœba alike are believed to proceed. But leaving the higher animals, as somewhat beyond the pale of our present inquiry, let us inquire whether the plant world gives any affirmative response to the question of "Nerves or no Nerves?" The flower we pull to pieces shows no sign of feeling—leaving "pain," as perfectly distinct from mere feeling, entirely out of sight—since, in the absence of consciousness in any form, "pain," as judged by the human standard, must be regarded as non-existent. As a rule, therefore, the plant world gives no response to outward stimulation. But are we to conclude from this observation that plants, as plants, are utterly destitute of feeling or sensation? By no means. A sponge gives no response when it is cut in pieces, yet the sponge is a true animal, whose parts resemble those of the amœba in nature and constitution. Moreover, if the absence of nerves in plants is to be held as negative

evidence, testifying in favour of their non-sensitive nature, we might equally well maintain that all the lower animals should be non-sensitive, since they do not possess nerves—a statement manifestly absurd.

But is it true that plants are invariably destitute of feeling? Ask the botanist what he can tell us about the sensitive plant, or about the Venus' fly-trap (*Dionæa*), not to mention the wood-sorrel (*Oxalis*) as well as numerous other examples of plants, which literally shrink and drop their leaves when you touch them, which capture insects for food, or which exhibit (as in the case of the telegraph plant, Fig. 1) continual movements of their leaves. Shall we say that a sensitive plant which drops its leaves on the slightest touch, and which may be chloroformed and rendered insensible like an animal, is non-sensitive, judged by the animal standard? Or shall we hold that its actions are in any way different from those of the animal sea-anemone, which, when touched, folds up its tentacles and contracts its body into a coloured mass, looking like nothing so much as one of the curiosities in the way of jellies or ices one sees in a confectioner's window? Assuredly not, must be our reply. There is no justification whatever for assuming that plant-sensitiveness is in any way different from animal-sensitiveness, whilst there is every justification for maintaining the uniform nature of sensation in animals and plants, and for the essentially "reflex" nature of the acts of both. Nay, we may go farther still, and assume that, could we but glance with the far-seeing gaze of imaginative science into the nature of plants and animals of the lowest grade, we should find that nowhere does life exist without sensation and feeling, or without the means for reacting in some way—however humble or ill-defined the fashion may be—on the world which acts upon and affects every living body. "Sensation" in this view becomes synonymous with life; and the acts of an animalcule become connected with the loftiest thoughts of man.

The conclusions to which our study tends are therefore: (1), our recognition of "reflex action" as a guiding principle in the common acts of man's life; (2), the extension of this principle to explain the acts of lower animals; (3), that we may find "nervous" acts performed (as in amœba, the jelly-fish, in lower animals generally, and in plants) in the common absence of actual nerves; whilst we may, lastly, note that, having regard to the facts of well-defined sensation and movements in many plants, and to the analogies of life at large, it may be assumed that all living organisms possess sensitiveness of degrees according to their rank in the scale of being. Sensation is possible in the utter absence of nerves. Such a study may thus not only afford some curious information regarding the habits of life in man and the lower beings, but may also show us the marvellous mystery and exceeding interest which prevail amidst the simple beginnings of life.

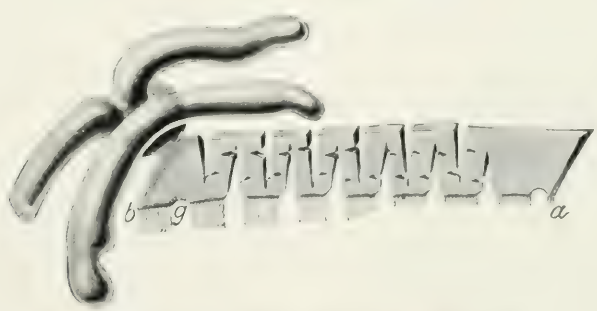


FIG. 6.—PART OF THE MARGIN OF A JELLY FISH.
(After Romanes.)

YEAST.

THE appearance of a brewer's fermenting vat in full work is at the same time striking and beautiful. At the beginning of the fermentation the whole surface is covered with a thick, light cream-coloured foam, which by degrees curls itself into wild, jagged little peaks of almost snowy whiteness, many of them twisted into the most fantastic forms. As the fermentation approaches completion the yeast loses its uneven surface, and settles down to a fine, thick, buff-coloured scum.

Now, let us try to learn as much as we can about fermentation without going too deeply into those parts of science which are unfamiliar to the general reader.

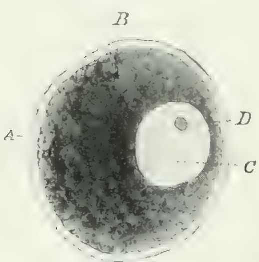


FIG. I.—THE CONSTRUCTION OF A YEAST-CELL.

A. Cell wall of cellulose.
B. Protoplasm.
C. Vacuoles.
D. Moving bodies.

When any liquid containing grape-sugar — such as the sweet juice of fruits, the extract of malt, or a mixture of treacle and water—is left exposed to the air and undisturbed at a temperature of about 60° Fahr., it becomes turbid in the course of a few hours, and after a short time a scum rises to the surface, a sediment falls to the bottom of the liquid, and bubbles of gas are given off, producing an appearance of boiling, from which the name fermentation (from the Latin *ferveo*, "to boil") is given to the process. These bubbles of gas continue to be given off for three or four days, or even longer, the time depending on the temperature, the composition of the liquid, and other similar circumstances. When the bubbles cease to appear, the liquid becomes clear, and is found to have lost its sweet taste, to have gained a spirituous one, and to have acquired intoxicating properties. The scum—or yeast, as it is called—which has been produced during the fermentation when introduced into sugar-containing liquids causes them to ferment much more rapidly than they would do if simply exposed to the air.

Such are the easily observed facts of fermentation. Let us now examine the process more in detail. First, as to the substance which forms the scum or sediment in fermenting liquids, and is known by the general name of yeast. To the unaided eye yeast appears to be a yellowish mud of froth; but if a little yeast be spread thinly upon a glass slide and placed under a microscope of low power, numerous oval or rounded colourless cells will be seen. Under a microscope of high power we find that it consists of slightly yellowish cells floating in a clear liquid. Some of these grains float alone, others are united in branching chains of several individuals. They vary slightly in size, those in the centre of the chain being generally the larger, while the average size across of the cells is about one-hundredth part of a millimetre.

FIG. 2. — YEAST UNDER THE MICROSCOPE.

A. Yeast cells at rest.
B. Chain of cells after rapid division.
C. Cell about to form spores.

On carefully examining one of these yeast-cells we shall find that it consists of a little bag or sac, made of a colourless, transparent substance similar to that which forms the fibrous matter of wood.

This bag contains a jelly-like substance known as *protoplasm*, and inside the jelly are one or two clear spaces or vacuoles. A number of minute globules of fat and particles of some proteid may also be observed in the protoplasm.

Fig. 1 is a diagram showing the construction of one of these yeast-cells on a large scale; while in Fig. 2 are drawings of various yeast-cells as seen with a high power of the microscope.* By adding a little solution of magenta or iodine to the yeast the protoplasm alone will be stained, and the details thus be rendered more easily observable. The nuclei of the cells, composed of densely granulated protoplasm, may then be seen; they are not apparent unless one of these stains is added.

Each single cell is a complete organism capable of independent existence, of growth, and reproduction, and, in fact, all the qualities which are commonly associated with life. The strings or chains of cells are colonies of individuals, all of which have sprung from one, the mother cell.

In any saccharine fluid, such as Pasteur's solution,* these yeast plants, referred to

... Ltd.

FIG. 3. YEAST IN THE FERMENTING VAT, SHOWING THE MECHANICAL METHOD OF "SKIMMING."

Photographed in a brewery belonging to Messrs. Meux & Co.

* Powell and Lealand, fitted with object-glass of $\frac{1}{12}$ inch focal length.

* *Pasteur's Solution.*

Water (distilled)	... ...	83·76 per cent.
Sugar (candy)	.	15·00 ..
Ammonium tartrate	...	1·00
Potassium phosphate	.	0·2
Calcium phosphate		0·02 ..
Magnesium sulphate	. ..	0·02 .

the great class of Fungi and the genus *Saccharomyces* by the botanist, have the power of setting up alcoholic fermentation, and at the same time increasing with great rapidity by the process which will be shortly described. That the fluid is fermenting means that the sugar ($C_6H_{12}O_6$) which it contains is being chemically broken up, and its constituents rearranged to form alcohol ($2C_2H_6O$) and carbonic acid gas or carbon dioxide ($2CO_2$). The carbonic acid gas comes off in bubbles, which rise freely and continuously in rapidly fermenting liquor, while the alcohol remains behind.

This we may observe if we place a few yeast-cells in a few drops of an easily fermentable liquid, and continue their examination with the microscope; we find that each yeast-cell begins to give out one or two little prominences from its side; that these grow larger by degrees, and into them part of the contents of the parent cell flow, the "bud" being linked to the parent cell by a narrow neck. These little prominences or "buds," when full grown, split off from the sides of the parent cell—frequently, however, not before they themselves have given rise to buds, and these in turn to others (as in B, Fig. 2), thus forming branching chains of linked cells.

Multiplication by budding, as described above, only takes place when the organism has plenty of available food—that is, when the yeast-cells are in contact with a liquid that easily undergoes fermentation. When such is not the case this vegetative process of reproduction ceases, and the multiplication takes place by asexually formed spores. To artificially induce the production of these spores the food supply of the yeast must be diminished, and a semi-starvation diet given it. This is most easily effected by thinly spreading some of the yeast upon slabs of plaster of Paris or thin slices of turnip, these being placed on moistened blotting-paper under a bell-glass in a room whose temperature does not fall below 60° Fahr.

M. Engel gave in 1872 an account of his method of investigating this reproduction by spores. He took some fresh brewer's yeast, and well washed it several times with distilled water, in order to take away from it all traces of fermentable liquid. The purified yeast was then spread in a thin film on a plate of plaster of Paris, which was kept well moistened with distilled water, and protected by a glass cover from the dust.

This film of yeast was examined from time to time with the microscope, and M. Engel noticed that while most of the old and full-grown yeast-cells died and broke up, the smaller ones grew larger, and appeared filled with a clear jelly. In a short time, however, two, three, or four spots appeared in the midst of the contained jelly, which gradually became granulated round them, and in about twenty-four hours each of these spots had developed into a complete cell or spore, and the group of two, three, or four spores was finally set free by the bursting of the wall of the parent cell. These spores remained fixed together for some time, and when introduced into a fermentable liquid reproduced themselves just as the original yeast did, thus proving their identity with it.

We have now learned all that mere microscopic examination can show us about the form and growth of this wonderful substance yeast. Chemists, however, tell us that yeast contains the elementary substances oxygen, hydrogen, nitrogen, carbon, phosphorus, potassium, and magnesium, and that these elements are united to form four compound substances of which the yeast-cells are composed. Now, these four are: (1) *cellulose*,* a sub-

* The cell walls in the Fungi do not assume the characteristic blue colour of cellulose when treated with iodine and sulphuric acid. The wall is believed to be formed of a modified form of cellulose, to which the name of fungus cellulose has been given.

stance similar in composition to the fibre of wood—of this the sac or cell wall is composed; (2) *protein*, a nitrogen containing substance somewhat similar to the white of an egg—this is the chief constituent of the jelly or protoplasm which forms the interior of the cell; (3) *fatty matter*, found also in the protoplasm; (4) *water*, existing in all parts of the cell.

Now, if a small drop of yeast the size of a pin's head be mixed with a pint of easily fermentable liquid (made by dissolving sugar and the ashes of the yeast plant with a little ammonium tartrate in water), the transparency of the liquid will not at first be impaired by the addition; but after some hours, if kept at a warm summer temperature, the liquid will enter into active fermentation, and the few yeast-cells introduced will have given birth to myriads. Since the number of yeast-cells has been greatly increased, the quantity of the cellulose and protein which compose them must also have been greatly augmented; but as the liquid itself contains no cellulose or protein, but only the materials which enter into their composition, it is plain that *the yeast-cells can manufacture protein and cellulose from* these materials.

Now, plants alone are capable of doing this, and therefore *the yeast-cell is a plant*.

[illegible]

FIG. 4.—REMOVING YEAST AFTER "SKIMMING."
Photographed in a brewery belonging to Messrs. Meux & Co.

We have already noticed that during the process of fermentation a gas is given off. This gas attracted observation more than three hundred years ago, when it was examined by Van Helmont, an old Dutch chemist. He found that animals could not breathe in it, neither could candles burn in it; and as it resembled in these respects the gas often found in caves, at the bottom of wells, and in other such places, he named it *gas sylvestre*,

that is to say, the gas or air that is found in out-of-the-way places. Later on it was found out that this gas was the same as that given off by heated limestone, by the breathing of animals, or by burning charcoal—in other words, the substance now known as carbonic acid gas.

The yeast plant, then, gives off carbonic acid gas. It is also destitute of starch and chlorophyll, or the green colouring matter of plants, and in these two particulars it differs from the great body of common plants. These are the essential characteristics of the Fungi, to which the yeast belongs.

Now, though yeast requires oxygen in order that it may live—for, like all plants and animals, it must breathe to live—it is by no means dependent on the air for its supply, for, as M. Pasteur demonstrated, if the air be excluded from the vessels in which the fermentation is taking place, the yeast, after exhausting the supply dissolved in the liquid, is able to obtain a further supply by decomposing the sugar, which is itself a compound of oxygen, hydrogen, and carbon.

In the beginning of this paper it was stated that any sugary liquid when freely exposed to the air at a favourable temperature would begin to ferment, and in time produce hosts of fully developed yeast-cells. The question then arises, Where do these yeast-cells come from? And to this question only two answers are possible—either they have been generated in the liquid, or have been introduced from without. The first of these two hypotheses—that of the "spontaneous generation" of ferments—was in former times accepted as the correct one; but a consideration of the following experiments will convince the reader that the second hypothesis is the more probable of the two.

In the first place, it has been found that the life of the yeast plant is destroyed by heating it to the temperature of boiling water (212° Fahr.). Three glass flasks, each partly filled with an easily fermentable liquid, are heated to the boiling-point. The neck of the first is drawn out and hermetically sealed before the blowpipe while the steam is still issuing from it, thus effectually precluding the contents from contact with the air; the neck of the second flask is plugged tightly with cotton-wool; while the neck of the third flask is left entirely open. The three flasks, being now allowed to cool down to between 77° and 95° Fahr., the temperature most favourable to fermentation, are carefully examined with a microscope from day to day. In a short time the liquid in No. 3 will enter into active fermentation, becoming turbid, giving off carbonic acid gas, and forming a scum of yeast-cells; while the contents of No. 1 and No. 2 will remain quite clear and free from fermentation.

We see, then, that sugary solutions eminently fitted to support the growth of the yeast plant will not enter into fermentation if excluded from the air, or if exposed to air filtered through a tight plug of cotton-wool, provided all existing yeast-cells in these solutions have been previously destroyed by submitting the liquid to a boiling heat; and, secondly, we observe that such solutions, though at first containing no yeast-cells, yet when freely exposed to unfiltered air develop hundreds of such cells, and enter into active fermentation, thus proving that the so-called spontaneous fermentation of saccharine liquids is due to the introduction of yeast-cells, or spores, which are floating about as fine dust in the air, and are capable of being separated from the air by filtration through a plug of cotton-wool. Pasteur showed that these air-carried yeast-cells may also be destroyed by passing the air through a red-hot metal tube, such air having no power to cause sugary liquids to ferment.

After having thus shortly considered the life of the yeast plant, let us now see what are the chemical and physical changes which are brought about during fermentation by the growth of this yeast as a whole.

It has long been known that all liquids capable of undergoing ordinary or alcoholic fermentation must contain sugar in some form or other, and also that the chief result of the fermentation is the changing of the great bulk of this sugar into alcohol, or spirit of wine, and carbonic acid gas. An experiment arranged in the following way is well adapted for showing this. Let a wide-mouthed bottle A (Fig. 5), holding about a quart, be half filled with a solution consisting of sugar and water, with a little yeast ash and a small quantity of ammonium tartrate. In the neck of the bottle fix a cork, through which passes the tube B, the other end of which goes down to the bottom of the test-tube C, which contains a solution of baryta water; from the cork of C passes a short tube, ending in the wider one D, which contains a few pieces of caustic soda, intended to prevent all traces of carbonic acid which may be in the air passing back into the baryta water contained in C.

On adding a small quantity of yeast to the solution in A, and keeping the apparatus in a warm room, the liquid will soon become turbid and begin to ferment, giving off bubbles of gas; these, passing into the baryta water in C, will produce a dense white precipitate of barium carbonate, which may be filtered off and afterwards examined. On the addition of hydrochloric acid it will give off carbonic acid gas, which may be recognised by its property of extinguishing flame and giving a white precipitate or sediment with lime-water.

During the fermentation a thermometer placed in the liquid will show that its temperature is higher than that of the surrounding atmosphere, this heat being due to the combination of the carbon of the sugar with oxygen to form carbonic acid—the process being, in fact, a slow burning, just as charcoal burning in air is a quick burning, the heat in both cases being due to the same cause.

After the fermentation is over, the liquid may be filtered from the scum and sediment of yeast, and distilled until about one-quarter of it has passed over into the receiver. This distillate still contains water, from which it should be freed by being poured over some lumps of quicklime placed in a large retort, allowed to stand for twenty-four hours, and re-distilled. The second distillate will be pure alcohol or spirit of wine, and may be recognised as such by its taste, smell, inflammability, and other well-known characteristics.

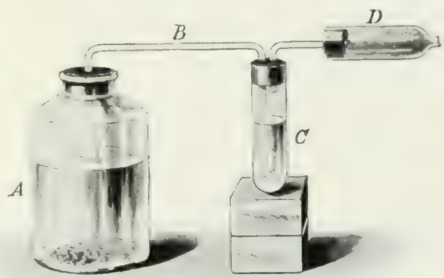


FIG. 5.—DEMONSTRATING THE NATURE OF FERMENTATION.

A. Bottle half-filled with sweetened water.
B. Tube joining A and C.
C. Tube filled with baryta water.
D. Tube filled with caustic soda.

In addition to these chief products—alcohol and carbonic acid gas—small quantities of two others are uniformly produced: one a somewhat rare one, called succinic acid, and the other a very common one—glycerine. And some very intricate experiments made by M. Pasteur led him to the conclusion that out of every hundred parts by weight of sugar which entered into the fermentation, ninety-five parts suffer decomposition into alcohol and carbonic acid, four parts

go to the formation of succinic acid and glycerine, while one part disappears, having served as nourishment for the yeast plant during its growth.

We have now seen that fermentation consists in two actions, which go on at the same time—viz. the growth of the yeast plant and the splitting up of the sugar into alcohol and carbonic acid, together with small quantities of succinic acid and glycerine; and, since the first of these never occurs without the second, we are led to the conclusion that the splitting up of the sugar in this remarkable way is the result of the growth and reproduction of the yeast plant.

We do not as yet know what is the precise manner in which the yeast plant effects these changes. All that we can say with certainty on the subject is that the chemical act of fermentation is essentially a correlative of the vital act, beginning and ending with it. There are several recognised species which set up alcoholic fermentation in various saccharine fluids. Thus *Saccharomyces Cerevisiæ* is the name given to the yeast plant of beer, whilst *S. ellipsoideus* is the ferment of wine. *S. mycoderma* is the so-called vinegar plant, which is to be found floating on the surface of fermented liquids.

In addition to the ordinary or alcoholic fermentation described above, the reader will do well to remember that there are others—the "acetic," "butyric," and "lactic," for instance—in each of which peculiar changes are brought about by certain living vegetable organisms.

Very soon after the discovery that the so-called spontaneous fermentations arose in most cases from the fermentable liquids being infected by ferment germs which were floating about in the air, the idea suggested itself to many chemists and physicians that certain classes of contagious diseases were very probably communicated in a similar manner; and it is now believed that all diseases contagious by inoculation, or more or less direct contact, are produced by fermentation of the liquids contained within the body, set up by foreign bodies of an organised nature similar to ordinary ferment-germs—viz. the *Schizomycetes*, or fission fungi, of the fungologist. These will, perhaps, better appeal to the reader under their popular name of bacteria and bacilli. As a rule, the yeast plants are placed with them, as being closely related in structure and general behaviour. The opinion is held in some quarters, however, that the yeast plants really belong to a much higher group of Fungi, the *Ascomycetes*, and that they are degraded relatives of the mischievous smuts and mildews which plague the tiller of the soil.

It has been shown without the least doubt that certain malignant carbuncles are really the result of the fermentation of the fluids of the body, which fermentation is carried on by the growth, reproduction, and decay of microscopic but easily recognised organisms; and just as it is the solid cells only of yeast which are capable of exciting alcoholic fermentation, so in cow-pox, glanders, sheep-pox, and other infectious diseases of animals the solid portions of the virus are those by which alone the disease is communicated.

A brief summary of the knowledge we have gained by this short study of the process of fermentation as seen in a brewer's vat shows that:—

We have learned that fermentation consists in the formation from sugar of alcohol, carbonic acid, and small quantities of glycerine and succinic acid; that this series of transformations is brought about in some manner by the growth, reproduction, and death of the yeast plant in the fermenting liquid.

We know that the single yeast plant is a simple cell—a bag of cellulose con-

taining a mass of jelly or protoplasm, in which are one or two clear spaces; that this cell can either reproduce itself by budding or by spores; further, that the yeast belongs to that curious class of plants called Fungi, although its particular status in that class is not yet definitely settled.

We have learned that yeast-cells are floating about in the air, from which they may be removed by efficient filtration, or destroyed by heat, and that they are ready to begin reproduction and set up fermentation as soon as ever they come into contact with a suitable liquid.

We see further that by considering this subject of ferment-germs physicians have been led to the conclusion that many diseases are really a kind of fermentation of the animal fluids, and may be conveyed by disease germs.

Finally, all of our experiments seem to show the impossibility of the "spontaneous generation" of ferments in liquids not previously containing them. The question of the spontaneous generation of living organisms has often been discussed, and some have maintained its possibility even recently; but all the evidence at present known is against the occurrence of any such phenomenon. The exceeding minuteness of these germs, the ease with which they may be conveyed by gentle air currents, in the clothing of visitors to the sick-room, their almost inexhaustible numbers and consequent ubiquity wherever conditions are at all favourable to their existence, are quite sufficient to account for the speed with which infection may be carried, without the interposition of the spontaneous germination theory.

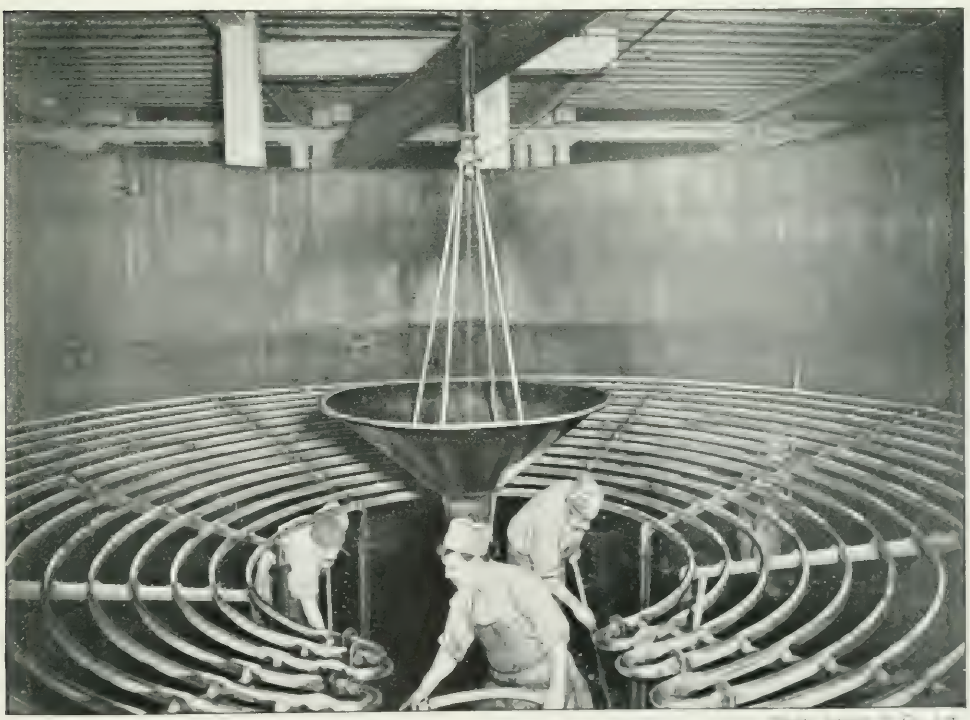


FIG. 6.—CLEANING OUT THE FERMENTING VAT.

From a photograph taken in Messrs. Meux & Co.'s Brewery.

THE VOLCANIC ERUPTIONS IN ST. VINCENT AND MARTINIQUE.

By PROFESSOR T. G. BONNEY, D.Sc., LL.D., F.R.S., F.G.S.

IN two successive days in the month of May, 1902, a sudden destruction came almost unawares on the northern parts first of St. Vincent, then of Martinique. The two islands, like the others of the Little Antilles, rise from a submerged saddle-shaped plateau between the profound depths of the Caribbean Sea and the Atlantic Ocean (Fig. 1), each having an active volcano at its northern end. They are about seventy-five miles apart, being separated by St. Lucia, which is rather nearer Martinique. The outline of St. Vincent is a rude oval, about eighteen miles from north to south and eleven from east to west. The island is almost wholly mountainous, and is formed of volcanic rocks. The crest of the range corresponds with its longer axis, and rises generally from 2,000 to 3,000 feet above sea-level, culminating at its northern end in the still active cone of the Soufrière (Fig. 3). Martinique is larger, being about forty-three miles long and twenty miles in greatest breadth, with a knot of mountains at the two ends, which are linked by a low ridge, the northern one, being crowned by Mont Pelée, some three hundred feet higher than the Soufrière, and, like it, active at intervals.

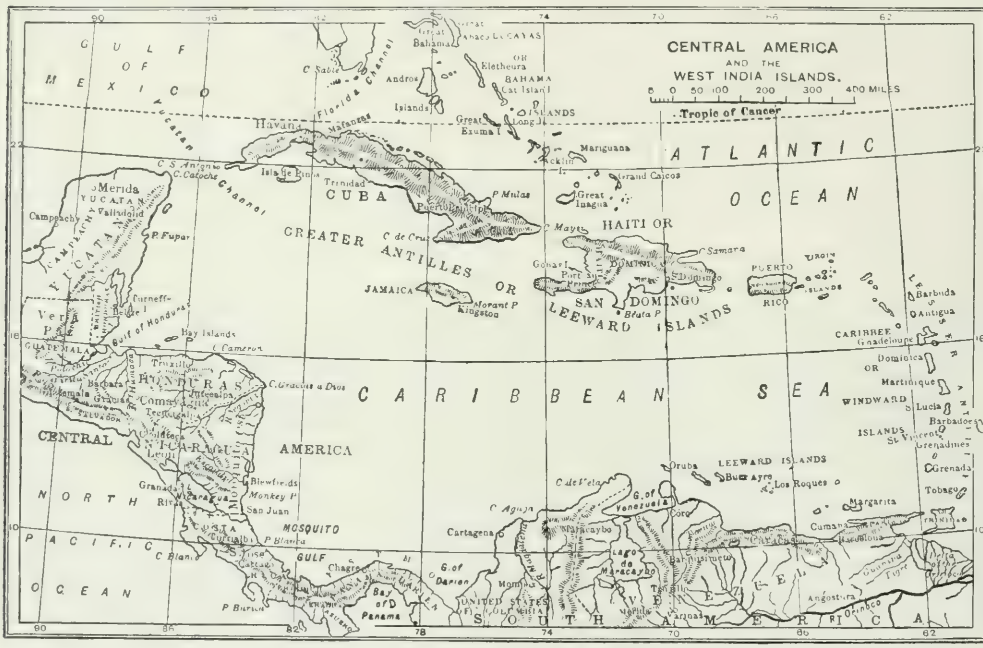


FIG. I.—MAP OF WEST INDIES.

For ninety years the St. Vincent volcano had been at rest, as if exhausted by its great outburst in 1812, when it hurled its ashes so high in the air as to cover Barbadoes, more than a hundred miles away to the east, with a thick carpet of

FIG. 2.—STEAM EXPLOSION IN THE WALLIBU VALLEY.

dust. The upper part of the volcano bore some resemblance to Vesuvius, for the broken ring of an ancient crater, like Monte Somma, half-encircled the principal cone. The actual crater is nearly circular, and about a mile in diameter, but on its north-east lip, separated by a

FIG. 3.—THE SOUFRIÈRE AND PART OF THE DEVASTATED REGION.

narrow ridge of volcanic material, is a subsidiary crater, which is supposed to have been formed in the eruption of 1812. The one is called the Old, the other the New, Crater. They were clothed with a rich tropical vegetation, and the former contained a lake, said to be 500 feet deep. On the eastern side their slopes descend rather rapidly to the sea, but on the western they shelve more gently downwards. This is called, from the remnants of the aboriginal inhabitants settled there, the Carib country, and on it were several of the most important sugar and arrowroot estates.

The eruption was not wholly without warning, for in the February of the previous year earthquakes had seriously alarmed the Carib inhabitants, but no signs of an outbreak were noted before May 6th. Even these were unperceived in the more thickly peopled eastern district, for, since that is the windward side, the summit was, as usual, hidden by clouds, and the explosions were mistaken

for thunder. But on the leeward the fact was recognised, and most of the inhabitants retreated from the actual slope of the volcano to Chateaubelair and the neighbouring villages, whence the discharges of steam could be seen to increase in intensity, and to be lit up at night with an ominous glow. Yet on the other of the island, is seamed with ravines worn deep into its flanks by the tropical rains (Fig. 4). These, soon after midday, were swept with boiling torrents of muddy water, and shortly before one o'clock the whole mountain was suddenly enveloped in vapour. At this time probably the crater lake was emptied by a few violent

From photo by Dr. Tempest Anderson.

FIG. 4.—RIDGES OF THE SOUFRIÈRE

By permission of the Royal Geographical Society.

flank of the mountain there was so little suspicion of danger that on the morning of the 7th work began as usual on the plantations, though at a quarter to eight the people in Chateaubelair saw a column of vapour shoot up from the crater to a height of 30,000 feet, and other signs that a serious eruption had begun. Not till about midday did those on the eastern side really take alarm, and then it was too late.

The Soufrière, like all the central ridge

explosions, and the heated water rushed down the mountain sides. Retreat was now impossible. By one o'clock the roaring of the volcano was tremendous; enormous columns of steam continued to ascend from the crater, the greater outbursts occurring every few minutes, and showers of stones fell all around. Up to this time the eruption, though a severe one, was of the ordinary type, but about two o'clock something happened which was without a precedent. "There was a

rumbling and a large black outburst, with showers of stones, all to windward, and enormously increased activity over the whole area." A strange dark cloud, laden with scorching dust, swept with terrific velocity down both flanks of the mountain side, burying the country in hot sand, suffocating and burning all living creatures in its path, and devouring the rich vegetation of the hill with one scathing blast. It is thus described by a spectator from a place of safety * : "We saw a solid black wall of smoke, falling into the sea about two or three miles from us. It looked like a promontory of solid land, but it rolled and tumbled and spread itself out until, in a little time, it extended quite eight miles over the sea to the west. Then began the most gorgeous display of lightning one could conceive. It was still bright daylight, but the whole atmosphere quivered and thundered with wavy lines, intersecting one another like trellis-work. We were encircled in a ring of fiery bayonets." Few lives were lost on the western side of the volcano, for most of the people had fled. Three or four men in a boat, near a village called Richmond, were caught by the cloud; the darkness was so complete that a man could not see his hand. Hot sand rained on them, making the sea hiss as it fell. They plunged into the water, and when they returned to the surface the air was still suffocating, so they dived again and again, till, when they were at their last gasp, they found it possible to

From a photo by Dr. Tempest Anderson.

FIG. 5.—MONT PELÉE IN ERUPTION

By permission of the Royal Geographical Society.

* Report by Dr. Anderson and Dr. Flett, "Proc. Roy. Soc.," Vol. LXX., p. 425. *See also* "Phil. Trans.," Series A, Vol. CC., p. 353.

breathe. One man, who was exhausted a little sooner than the rest, and forced to cling to the gunwale, had the tops of his ears severely scorched. On the eastern side the victims were numerous. Those who were out of doors saw the cloud sweeping down the mountain, and fled for refuge to their huts or into the plantation works. But the deadly blast found them there. Eighty-seven had crowded into one small room, and all perished. Only those escaped who had shut themselves up in the rum cellars, or in substantially built houses with closed doors and windows. The suffocating cloud, which only lasted a few minutes, was like the blast from a fiery furnace, smelt strongly of sulphur, and was charged with hot dust, which often burnt clothes and all exposed parts of the body. The whole north end of the island was now in a "darkness that might be felt." The survivors had to crawl or grope their way along the roads. Fine ash, with occasional showers of large stones, rained down over the whole country. Some of the latter were so hot as to set fire to the "trash" roofs of native huts in Kingstown, twelve miles away. The earth trembled incessantly, and "the roaring of the mountain was terrible—a long-drawn-out, continuous sound, resembling the roar of an animal in great pain." By half-past five that afternoon the dust was falling in Barbados, a hundred miles to the east. It had travelled against the trade wind, and thus must have been shot up through it into the current of the counter-trades—a vertical flight of at the very least two miles, and it was estimated that about 1,700,000 tons were distributed over the island. In the northern part, or in nearly a third, of St. Vincent, everything was changed: the vegetation was gone, trees were converted into blasted skeletons or overthrown, buildings were wrecked, a grey dust, like a deep snowfall, had buried everything, and the ravines which scar the side of the Soufrière were choked with volcanic *débris*. Puffs of steam were still being ejected from the crater, and showers of fine dust falling on the leeward side of the mountain, but the worst was now over—at any rate, for a season.

When Dr. Tempest Anderson and Dr. J. S. Flett, the Royal Society's commissioners, arrived, less than five weeks after the catastrophe, the volcanic *débris* was everywhere furrowed by rain rivulets. The work of excavation led to a curious phenomenon. The ashes ejected from the volcano were often very hot, so the accumulated material, as it is a bad conductor of heat, remained at a high temperature within a quite moderate distance from the surface. As the swollen torrents rush down the ravines, they undermine the steep banks of loose ash, great masses slip down, and when the hot ash tumbles into the water, "an immense cloud of steam rises in the air to hundreds of feet. It expands in great globular masses exactly like the steam explosions from a crater, and as it drifts away before the wind fine dust rains from the cloud" (Fig. 2). Drs. Anderson and Flett witnessed a wonderful series of these explosions in the valley of the Rozeau Dry River one day as they were descending from the summit of the Soufrière to Chateaubelair. "After every landslip a column of muddy water rose up to about 200 feet, carrying with it pieces of stone. Immense quantities of steam shot up to 700 or 800 feet in the air. It resembled an enormous geyser of black mud and steam." Each rainstorm converts the dry gulleys into torrents, and on this occasion they found their way blocked by a torrent of hot, muddy water.

The fatal discharge apparently took place from the old crater, but its outline has not been materially altered, though

Photo., Jas. J. [illegible], M.D.

FIG. 6.—RUINS OF ST. PIERRE, "THE PEARL OF THE LESSER ANTILLES"

Once a thriving town with 25,000 inhabitants.

the lake, of course, has been emptied. The level of the island is apparently unaltered. At one place, indeed, part of the foreshore, with a road, has disappeared, but it is doubtful whether this is more than a kind of landslip. The loss of property has been very great, while that of lives has been something like sixteen

FIG. 7.—A CLOSER VIEW OF THE RUINS OF ST. PIERRE.

hundred. A large area of very fertile land is ruined, and many buildings, with much valuable machinery, have been destroyed.

The English commissioners passed on to Martinique, to which Professor Lacroix, a very eminent French geologist, was at once despatched by his Government. The story of the Montagne Pelée is very similar in its incidents, but yet more tragic in its results than that of the Soufrière. The form of the islands and the position of the volcanoes are much alike, but the northern end of Martinique, on which Pelée is situated, projects a little towards the west.

Like the Soufrière, the mountain is seamed and scarred with ravines and valleys; and, by the seaside, at the mouth of one of these, and rather less than five miles distant from the summit, stood St. Pierre, "the pearl of the Lesser Antilles," a city with more than 25,000 inhabitants. The volcano had been at rest for just half a century, and seems not to have been regarded as a dangerous neighbour, so that here also the catastrophe was unexpected. Pelée had, however, given a little longer notice than the Soufrière, for on April 25th it began to eject steam, and this was followed on May 2nd by showers of ashes and stones, which were projected with loud detonations, occasionally to a

distance of seven or eight miles. Three days afterwards boiling mud, probably indicating the emptying of a crater lake on the upper part of the mountain, swept down the glens. This drove many people into the city, so that, though not a few had taken flight in dread of an earthquake, on the morning of May 8th it probably was as full as usual. St. Pierre had its daily paper, and the editor gave notice on the 7th that, as the following was Ascension Day, the next number would appear on the 9th. That promise was not fulfilled, for hours before Thursday evening no one was left to write, edit, print, sell, or buy the paper. St. Pierre was a city of the dead—a heap of blazing ruins (Fig. 6).

The volcano was not specially active; the morning of Ascension Day was bright, and the people were hurrying along the streets to church, when suddenly—between a quarter- and half-past eight—a tremendous report was heard, a huge black cloud of intensely hot dust (Fig. 5), speckled with glowing stones and scintillating with lightning, swept down from a fissure in the edge of the crater like an avalanche upon the city, which stood exactly in its path. For a few moments people were dimly seen, but more often heard, running shrieking about the streets; then there was silence, broken only by the crackling of flames, kindled by the incandescent missiles, and the detonations of the volcano. The avalanche struck the harbour where vessels were moored; it threw some on their beam ends, set several on fire, and covered everything with scorching *débris*. In most cases all on board perished, but the skill and bravery of Captain Freeman, of the *Roddam*, aided by the fact that they had only just made fast, succeeded in saving the ship and some of the crew. This is his story: "An avalanche of lava was upon them. It immediately caught the town afire as it passed over it, likewise the shipping. It struck his ship with the force of a mighty hammer, and the lava rained upon the deck. . . . His first thought was to try and save his ship and such of his crew as were still alive. He rang the bell for full steam astern, and the heroes below turned on the steam. He had time to slip his anchor, and he was off. As his stearing gear was rather difficult to manage (his hands were so badly burned that he had to work with his elbows), he once or twice nearly ran foul of the steamship *Roraima*, which was on fire. He saw two figures standing on the bridge with arms folded, heroically awaiting their end. One of them waved a good-bye to him."*

Some of the woodwork on the *Roddam* was ignited, but it fortunately had an iron deck, and when it reached St. Lucia the mass of stones and dust removed from this was estimated at 120 tons. But twenty-six of its crew were killed or died of their injuries.

St. Pierre was a heap of ruins; trees were blasted and scorched on the side facing the avalanche, and were often broken or torn up. A statue of the Virgin, which overlooked the city, was hurled from its pedestal and carried onwards to a distance of forty feet. Practically nothing was left standing, and no one alive, in the path of the avalanche, except a prisoner in a closely shut cell in the lower part of the town. How many perished will never be known; the dead were burnt in the ruins of the houses, or were buried beneath the ashes.

The volcanoes have more than once renewed their violence. Dr. Flett and Dr. Anderson were so fortunate as to be near witnesses of an outbreak on July 9th, which was no doubt a repetition, though on a slightly diminished scale, of that which had destroyed St. Pierre. As Fort de France, the principal town

* "Phil. Trans.," Series A., Vol. CC., p. 483.

remaining in Martinique, was too far away, they had hired a sloop to serve as their home while studying Montagne Pelée. They spent the morning in examining the ruined city and neighbourhood. The volcano was quiet, and they were planning an ascent for the morrow. But early in the afternoon the puffs of steam from the crater became larger and anchor and setting sail. The cloud came on, lit up by lightning flashes, but on reaching the water it seemed to halt and form a great black, undulating pall. Their boat slowly slipped away, the summit of Pelée began to clear, and they saw a glare on the clouds above the fissure. This grew brighter, and red-hot stones came bowling down the mountain.

Photo: Jas. Johnson, Esq., M.P.

FIG. 8.—RUINS OF ST. PIERRE: LOOKING SOUTH.

more frequent. Towards evening they were shot up fully a mile high above the cone, and darkened with dust. They anchored for the night near a little fishing village not quite half a league south of St. Pierre, and were sitting on deck in the twilight, watching the volcano, when suddenly a black cloud appeared over the fatal fissure. Instead of rising, it seemed to hang suspended and to increase in size. But almost immediately they discovered that it was rolling down the mountain side, and they were directly in its path. All joined in raising the

"Suddenly a great yellow or reddish glare lit up the whole cloud, which veiled the summit.* . . . Then from the mountain burst a prolonged angry growl—not a sharp detonation or a series of detonations, such as we had heard before when the hot stones were launched from the crater, but a long, low, rumbling sound, like the sullen growl of an angry wild beast. . . . Then, in an instant, a red-hot avalanche rose from the cleft in the hillside and passed over the mountain slopes right down to the sea. It was dark red, and

* "Phil. Trans.," Series A., Vol. CC., p. 404.

in it were brighter streaks, which we thought were large stones, as they seemed to give off tails of yellow sparks. They bowled along, apparently rebounding when they struck the surface of the ground, but never rising high in the air. The main mass of the avalanche was a darker red, and its surface was billowy, like a cascade in a mountain brook. Its velocity was tremendous. . . . The similarity to an Alpine snow avalanche was complete in all respects, except in the temperature of the respective masses. The red glow faded in a minute or two, and in its place we now saw, rushing forward over the sea, a great, rounded, boiling cloud, black and filled with lightnings." Right in the path of this their vessel was becalmed, for the gentle wind had dropped, but at the critical moment a slight breeze sprang up, which carried them on. The cloud rose from the sea, became whiter in the upper part as the steam disengaged itself from the dust, and passed over their heads. As it came above them, a hail of pebbles fell on the deck. They picked up the first; it was about as large as a chestnut, and cold, so they knew all danger was past, but they wisely lost no time in retreating to Fort de France.

From a photo by Dr. Tempest Anderson.

FIG. 9.—TREES OVERTHROWN BY THE BLAST OF AN AVALANCHE IN THE ALPS.

By permission of the Royal Geographical Society.

In both islands almost all the deaths were due to the same cause. But what was this? It was not a flood of glowing lava, in the ordinary sense of the word, nor, as a rule, lightning, nor vapour, inflammable or mephitic. Sulphurous and other gases were no doubt present in the cloud, but not in fatal quantities, as the commissioners are convinced, both of whom are well qualified to form an opinion,

and have carefully investigated the evidence. It was an avalanche, mainly of hot dust and steam, which descended, like those in Alpine regions, by gravitation. This is Dr. Flett's explanation of its peculiar character. All lavas contain a considerable quantity of extremely hot water, which is mostly discharged as steam when they issue from the earth. The *débris* from these volcanoes contains a rather high proportion of small minerals, and the formation of these would increase the quantity of water dissolved in the molten residue, the temperature of which would probably be from 1,800° to 2,000° Fahr. If a quantity of this were suddenly impelled up the "throat" of the volcano and vomited over the crater's edge, it would be at once relieved from great pressure, and the vapour would instantaneously expand. If the material had been homogeneous, it might have bubbled up into a stony foam, like the pumice ejected from Krakatoa in 1883; but that scattered host of tiny crystals would interfere with uniform expansion, and the whole mass would explode, not from a few but from innumerable centres, and would thus be shattered, probably during the first few seconds, into countless particles, which very likely would be again and again disrupted, till that which within the crater had been an incandescent liquid had been converted into an avalanche of hot dust, mingled with steam, and stirring up, as all such do, a mighty blast. So the history of the Soufrière and the Montagne Pelée has added a new terror to volcanic eruptions. Vesuvius was again active early in April, 1906, but that is an event the treatment of which does not fall within the scope of the present article as defined in its title.

From a photo by Dr. Tempest Anderson.

FIG. 10. THE MOUTH OF THE WALLIBU FROM THE SEA.

By permission of the Royal Geographical Society.

CLOUDS AND CLOUDLAND.

WHEN water is evaporated into the air under the influence of heat, the vapour so raised is scattered invisibly amidst the air particles. Both the air particles and the molecules of the water are, however, so minute, and so widely severed in this state, that the vibrations of light pass *almost* as freely and as unimpeded amongst them as they do through empty space. The mixed vapour and air are virtually transparent —that is to say, they allow objects of various kinds to "appear through" or from beyond them in their proper conditions of colour and form, instead of becoming visible themselves. It was essential that this should be the case if the surrounding objects of material Nature were to be freely visible to the eyes of animals living in the midst of circumambient air.

This absolute invisibility and transparency of aqueous vapour, even under the circumstance of very considerable abundance, is instructively illustrated in the fact that steam is quite imperceptible to the eye so long as it is in its actually vaporous state. If the eye could penetrate into the interior of the boiler of a steam engine when the part above the water is filled with a pressure of steam almost strong enough to burst asunder the cohesive tenacity of the iron plate, it would be found that such steam was as absolutely invisible as the fine breath of vapour which rises from the earth in bright noontide sunshine. The steam which issues from the spout of a kettle of boiling water presents no visible trace to the eye until it has been thrown some distance away into the outer freedom of the air. It only becomes visible as white mist when it has ceased, at that distance, to be actual steam.

The experiment shown in Fig. 1 makes both these facts clear. A glass flask, half filled with water, and fitted with a pierced cork through which projects a glass tube with a narrow orifice, is placed upon a retort stand, and the contents, by means of a spirit lamp or a Bunsen burner, are brought to the boiling point. The space above the bubbling water is seen to be quite free from visible vapour, and the cloud above the exit tube is not visible at the point of emission.

The change which takes place when invisible vapour is transformed into visible mist is a very decided one. It is not merely that there is an increase in the quantity of the aqueous particles that are present in the air, for, as a matter of fact, there is a larger abundance of vapour in the clear air of a summer noontide than there is in the thick air of a winter sunset. The change which is brought about is an actual transformation of material state. It is a conversion of air-like vapour into water. The visible particles of mist are clusterings of molecules of water into groups of visible and therefore of considerable dimensions. In the white mist the molecules of the water are not evenly and widely scattered. They are so grouped that there are larger spaces between the clustering particles than there are between the molecules of the vapour, and there are many molecules connected together in these clusterings. It is this gathering together of the molecules in isolated groups, with comparatively blank intervals between, which is comprised in the process familiarly spoken of as "condensation." A similar state is produced to that which is found when liquid water is mechanically broken up into spray. It is then in the condition which has been not inaptly spoken of as

"water-dust."* Thus, in waterfalls of great height the particles of the water get so severed from each other by the resistance of the air which they have to pass through that, before they reach the ground, they present themselves only as "water-dust," or drifting mist. Mist is thus a sort of intermediate state lying midway between water and vapour. It appears when water is scattered into spray, and also when vapour is condensing into water.

The clustering of water molecules into granular specks is easily seen in mist by the help of a magnifying glass. Small, opaque bodies, which must contain a very considerable gathering of water molecules in each, are then discerned. These bodies have manifestly a rounded or globular form, such as they would wear if they were minute drops.

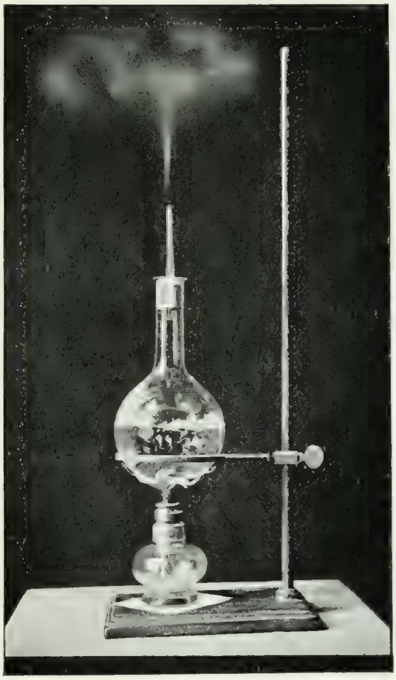


FIG. I.—HOW CLOUDS ARE FORMED.

A flask of water is placed over a spirit lamp or Bunsen burner. As soon as the water begins to boil a miniature cloud is formed a few inches above the mouth of the flask.

The fabrication of visible mist from the condensation of invisible vapour is familiarly illustrated every day in the puffing escape of the waste steam from the funnel of the locomotive as it runs panting along the rails. The white, rolling mist which is left in a thick trail behind the funnel of a locomotive engine is, in all essential particulars, cloud. Its close kinship to the heap-cloud which floats above it in the higher region of the air is manifest at a glance. The steam-puff is a miniature cloud wreath artificially formed. It is visible to the eye on account of its coarse-grained texture. It is not freely permeable to light, because the clustering spherules, or vesicles, arrest the luminous vibrations which fall upon them, and send these back to the eye, and because these light-reflecting spherules are distributed in a deep bed, in which the more remote individuals present themselves through the clear spaces that lie between the nearer ones. The cloud is white or grey, accordingly as its spherules reflect, or absorb and hold, more or less of the incident light. It is dark when it holds back the chief part of the luminous vibrations which fall upon it, and it is white, like snow, when it freely reflects the whole. It should also be observed that the position of the sun with regard to any cloud must of necessity greatly influence its appearance. Figs. 3 and 4 show how different clouds of the same type will appear when (i.) the sun happens to be in front, and (ii.) when the light is behind and the clouds are represented as dark silhouettes.

The fundamental and primary form in which natural cloud appears is the very beautiful and distinct one which is seen on most ordinarily fine days sailing grandly across the blue sky, and which is designated the *Heap-cloud*, *Mount-cloud*, or *Cumulus*, because it assumes the aspect and shape of rounded masses piled up in heaps. (*See* Figs. 2, 3, and 4.)

* *See* "Rivers and Their Work," CASSELL'S POPULAR SCIENCE, Vol. I., p. 94.

Professor Tyndall happily speaks of the rolling masses of the heap-cloud or cumulus as being the "capitals" of underlying columns of warm air. Whereever the air is heated by resting upon the warm ground it is forthwith fashioned into an ascending, although unseen, air-column, which crowns itself with a capital of wreathing cloud as soon as it has got high enough to chill the entangled water molecules into clustering spherules of condensing liquid.

But in order that we may have a complete comprehension of this process of cloud manufacture it must be understood that these mist capitals of the warm air-columns are cut off from the pillars, and wafted away as soon as they have been formed. The heap-clouds invariably are seen *to drift along in the sky* (Fig. 5). The fact simply is that as soon as the ascending columns of warm air reach the cool upper regions, where transverse currents, instead of ascending ones, prevail, the rolling mist wreaths which are precipitated from the air are carried away by the wind. The so-called *floating* of the cloud is simply a matter of *drift*. Water is many times heavier than air, consequently it must fall when deposited in air, as, indeed, it is actually seen to do in the case of rain-drops. If clouds, therefore, are composed of liquid water gathered out of the vapour, they should fall and not float. Some ingenuity has been expended by scientific men in the attempt to account for this apparent anomaly. No large amount of intelligence, however, is really required to enable this to be done satisfactorily. A glance of the eye on the white mist heaps in the sky is enough to furnish the full solution of the mystery. Clouds never rest still in air; they are at all times *in motion;* they are always in the act of being blown along by the wind. When

From a photo. by E. Wyse, Southport.

FIG. 2.—A GOOD SPECIMEN OF "CUMULUS" OR HEAP-CLOUD, WELL ILLUMINATED.

These clouds are often seen on fine days, but they presage rain if they increase greatly in size as the evening falls.

rain-drops fall at the time that a strong wind is blowing, even they are observed to be carried a considerable distance along; and if the rain-drops were lighter than they are they would be carried still farther by the wind before they finally reached the ground. If, for instance, they were hollow, air-filled balls, like balloons, instead of being compact drops of liquid, they would assuredly drift upon the wind long distances, and this, it will be remembered, is precisely what cloud spherules are. They are hollow balls, constituted of the lightest and thinnest conceivable films, and therefore possessing very large surfaces in proportion to their weight. They are just in the condition which fits them to be seized and hurried along by the drifting air currents. When clouds exist in really still air, their spherules do fall. It has been ascertained that aqueous mist, by falling through some three thousand feet of air, can acquire a downward velocity of something like fifty inches per second. It would, indeed, fall with the headlong impetuosity of a leaden bullet or a stone, but for the resistance which it encounters in making its way down amongst the air particles. When, therefore, the air is itself moving, instead of being at rest, this resistance to its descent becomes an actual carrying power. In all probability, electrical force at times has something to do with the suspension of cloud. But there can be no doubt that, in the main, the result is merely the effect of a mechanical influence—that it is a case of drift rather than of buoyancy. The notable instances in which clouds appear to be still are all simply illusions. In such cases the cloud is in the process of being dissolved away at one edge as fast as it is deposited at the opposite one, and so it is the visible form only, and not the substance, which is still. The "tablecloth" which frequently covers the top of Table Mountain at the Cape of Good Hope is a cloud of this character. The moist air from the south-east is blown from the warm sea up the slopes of the mountain, until it is high enough to deposit its vapour as white mist, and it then passes over the flat summit of the mountain and falls on the opposite side, until it gets back into the lower and

Phot.: F. C. Hepworth.

FIG. 3.—LIGHT IN FRONT OF "CUMULUS."

Phot.: F. C. Hepworth.

FIG. 4.—LIGHT BEHIND "CUMULUS."

warmer region, where the white mist is again dissolved into transparent vapour. In mountainous countries it often happens that all the summits of the lofty mountains are cloud-capped, whilst the intervening spaces of the atmosphere are clear. The same explanation applies to this. The cloud is deposited where the air is chilled by the close neighbourhood of the snow-covered summits, but is dissolved as soon as it is drifted away clear of the mountain into the warmer stretches of air. The white cloud-caps are thus not stationary clouds, but fresh clouds continually formed, and as continually dissipated as they move from the place where each white cap is seen.

Many attempts have been made to classify clouds, and to the ordinary observer who notes the wonderful variety of form and colour presented by the firmament, at morn, noon, sunset, and at night, in calm and storm, it would seem a well-nigh hopeless task to confine that splendid disorder to tabular form. Luke Howard, the well-known meteorologist, was the first to take the work in hand in 1803, and the classification which he decided upon has been adopted by most other writers up to the present time. Howard placed the cloud under four different heads—the *Nimbus* (Fig. 6), the *Stratus*, the *Cumulus* (Figs. 2, 3, and 4), and the *Cirrus* (Fig. 7), and these fundamental forms pass into one another, and we then have such combinations as the *Cirro-cumulus*, *Cirro-stratus*, and *Cumulo-stratus*, it being often very difficult to say which a particular formation of cloud most resembles.

FIG. 5.—ILLUSTRATING THE DRIFTING OF CLOUDS.
Clouds are never quite stationary; they are in reality being carried along by air currents. Their apparent suspension in the air is due primarily to this motion.

A more comprehensive system of cloud nomenclature was that agreed upon at a meeting of the International Meteorological Committee at Upsala in August, 1894, and a diagram of the system, illustrated by photographs, forms the frontispiece of a very charming book by Mr. R. Inwards (late President of the Meteorological Society), "Weather Lore." This international system adopts the following

names, beginning with the lowest clouds :—

NAME.	ALTITUDE.
Stratus	0 to 3,500 ft.
Nimbus (rain-cloud) ...	3,000 to 6,400 ft.
Cumulo-nimbus (storm-cloud)	4,500 to 24,000 ft.
Cumulus	4,500 to 6,000 ft.
Strato-cumulus	about 6,500 ft.
Alto-stratus	10,000 to 23,000 ft.
Alto-cumulus	10,000 to 23,000 ft.
Cirro-cumulus	10,000 to 23,000 ft.
Cirro-stratus	average 29,500 ft.
Cirrus	27,000 to 50,000 ft.

which includes the terms *Mare's-tail* (Cirrus) and *Mackerel Sky* (Alto-stratus) (Figs. 7 and 8), which are so excellent in their descriptive truth that they are not likely to become obsolete. Most probably other nations have their own popular names for different appearances of the sky, just as each nation has adopted a certain recognised classification, despite the efforts of the international committee to bring about a uniform system.

From a photo by E. [illegible], [illegible].

FIG. 6.—THE "NIMBUS" OR RAIN-CLOUD.

These clouds mean business, and they almost invariably bring heavy showers. The "nimbus" is frequently seen in spring.

Commander D. Wilson-Barker, who has paid much attention to the photography of cloudland, and who has written an excellent little book on "Clouds and Weather Signs," takes a more simple course in placing clouds under two well-defined types—*Stratus* and *Cumulus*—and making them a basis of classification. And he adopts the terms *Shower-cumulus*, *Squall-cumulus*, *Pillar-cumulus*, and *Roll-cumulus*, which well describe certain aspects of the heaped clouds. Then there is a certain loose popular nomenclature

The heap-cloud, or cumulus, is properly a day cloud. It begins to appear in the early morning, as the ground gets warmed enough by the sunshine to establish ascending currents of air. It rises into higher regions of the atmosphere and assumes its largest dimensions soon after noon, and it then sinks and dwindles away towards evening. It belongs also properly to the mid-region of the air, ascending to a somewhat higher elevation at mid-day, and sinking to a lower one in the evening. It is also a cloud of land

districts rather than of the sea, as heated ground is required to establish the upcast of the air currents. But when it has once been formed over the land it is capable of being drifted away long distances over the sea, as it invariably is in the great currents of the trade winds which prevail in the intertropical regions of the ocean. When these cumulus clouds observe their normal rule of growing in size and rising in height at mid-day, and of diminishing in size and sinking in the evening, they are invariably indications of settled weather; but when, on the other hand, they grow in size and in density as they subside in the evening, they indicate increasing moisture and greater chill in the lower regions of the atmosphere, and may be regarded as certain harbingers of approaching rain.

In settled fine weather, when there is not moisture enough in the ascending currents of the air to form heap-clouds in the mid-region of the atmosphere, faint streaks of white cloud appear flecking the blue sky-canopy, far above the region where the heap-clouds should sail. A few delicate threads are first pencilled out on the azure background, and these then grow by the addition to them and interlacing with them of new strands. The streaks sometimes assume the form of feathers, or of tufts like flowing horse-tails; sometimes they are parallel to each other, and sometimes they cross and interlace like the meshes of a net; sometimes they diverge like the fingers of a hand, and very frequently they are curled up like locks of hair. In all these diversities of form, however, they are of a thin, filmy nature, and in all they present themselves only at very high elevations. These filmy cloud streaks of very elevated regions are all classed as the *Curl-cloud*, or *Cirrus*.

When, in consequence of a sudden increase of moisture from the drifting in of a vapour-laden wind, the streaks of the curl-cloud in the upper region of the air become more abundant, they at length get woven out into a continuous stratum, or bed, and at the same time settle down to a lower level on account of their augmented density. The cloud, however, then receives a new name amongst meteorologists. It is termed the *Thread-cloud*, or *Cirro-stratus*. It is properly the streak-cloud, or Cirrus, passing into the state of *Sheet-cloud*, or *Stratus*. The streaks are woven out into a thin layer or misty web, which is thinned gradually away towards the edges all round, and therefore assumes the appearance of a long, narrow band with pointed extremities when seen in profile, low down towards the horizon.

It is from this peculiarity that it has received the familiar designation of thread-cloud. In its completed form it is a cloud of considerable lateral extent and of small perpendicular depth; the fibres and streaks of the cirrus, in its fabrication, settle down into a horizontal position, approach each other, and finally interweave, or fuse themselves into a continuous layer. The streaks not uncommonly assume the grained appearance of polished wood. The beds are almost always thick in the middle and thinned out towards the edges. In the distance the pointed cloud-masses occasionally look like shoals of fish. The mackerel sky is also caused by a variety of this kind of cloud (*see* Fig. 8). The cirro-stratus, when abundantly developed and persistently maintained, almost certainly indicates the approach of wind and rain.

The *Curdled-cloud*, or *Cirro-cumulus*, is the sheet-cloud, or cirro-stratus, in the process of being re-modelled into miniature cumuli, and is regarded as a kind of intermingling of cirrus and cumulus, as its compound technical name indicates. The cirro-cumulus was well described by Luke Howard as consisting of " small,

dense, roundish cloud-masses, grouped like a flock of sheep." It is the cloud of the mottled sky which occurs so frequently in summer, and is also occasionally seen in the intervals between showers in winter time. It is constantly formed from the subsidence of cirro-stratus into the lower and warmer regions of the air, and when this is the process of its formation the flocculi of the cloud are slowly and gradually dissolved away. It not uncommonly appears at the same time with the cirro-stratus, and alternates with it, the one or the other form predominating accordingly as there is increasing deposit or loosening and dissolving away of the cloud-mass. As a general rule, the true curdled-cloud indicates increasing warmth, diminishing moisture, and a tendency towards fine weather.

The streak-cloud, however, is not the only cloud which is prone to gather into continuous masses. The heap-cloud, in very moist states of the atmosphere, does the same thing; but the accumulation is then deep as well as broad. The cloud-mass is piled up higher and higher, and the rolling heaps are connected together by horizontal beds. The cloud is then looked upon as being a combination of the heap-cloud with the streak-cloud, and is on that account technically distinguished as *cumulo-stratus*.

From a photo by E. [illegible]

FIG. 7.—CURL-CLOUD OR CIRRUS.

Cirri are the highest of all clouds, and some of the most beautiful: they are always indicative of fine weather.

The rolled form of the cumulus can generally be traced for a long time in the thickening and growing mass. In the first instance it towers up in projecting summits above the stratified base, but subsequently the rolled protuberances overflow at the sides, and hang down from the flat bed, until at last the whole sky gets to be filled with one dense and undistinguishable mass. But when this dense mass floats away towards the distant horizon it is finally seen there as a

flat drift overlapped by rolling summits which at times very closely simulate the aspect of snow mountains.

The immediate tendency and the final destiny of the cumulo-stratus cloud are obvious at a glance. It is the parent of the *Nimbus*, or *Rain-cloud*, which was also classed by Luke Howard as *cumulo-cirro-stratus*, because it was regarded by him as a confused intermingling of heap-cloud, streak-cloud, and sheet-cloud—a congeries of clouds pouring forth rain.

In the formation of the rain-cloud the lower clouds spread out in all directions until they unite into one uniform and compact homogeneous mass, from which the gathering rain-drops fall. The distinctive characteristic of the rain-cloud is the thick, impenetrable confusion of its homogeneous mass, and the streaky, undefined shading away of its outer edges.

There is one hitherto unnamed yet remarkably distinct and interesting form of cloud, which has been brought to the notice of meteorologists by Mr. Clement Ley. It is a very high cloud, rarely appearing so near to the ground as 14,000 feet, and is essentially a continuous layer of sheet-cloud, with numerous turret-like protuberances rising up out of the horizontal bed.

FIG. 8.—A MACKEREL-BACK SKY.
This is caused by the presence of "thread" clouds or cirro-stratus. Wind and rain are coming.

This cloud is of an exceedingly beautiful form, and is not unfrequently mistaken for a modification of cirro-cumulus. It has, however, nothing of cirrus about it, and should rather be classed with cumulo-stratus, to which it is more naturally allied. It is generally seen during the prevalence of very hot weather, and is essentially connected with great electrical disturbance in the higher regions of the atmosphere. It is the constant precursor and herald of violent thunder-storms.

Hitherto meteorologists have all agreed on one point, and that is, that clouds of all denominations are caused by the condensation of aqueous vapour. But there is another explanation for the presence of the attenuated forms of clouds which have been observed at a height of many miles above the surface of the earth.

Professor Dewar called attention to the matter in his presidential address to the British Association at their meeting at Belfast. He was dealing with that subject which he has made his own—that of extremely low temperatures. Referring to the state of the atmosphere in its higher regions, he said, "The temperature at the elevations we have been discussing would not be sufficient to cause any liquefaction of the nitrogen and oxygen, the pressure being so low. If we assume the mean temperature as about the boiling point of oxygen at atmospheric pressure, then a considerable amount of the carbonic acid gas must solidify as a mist, if the air from a lower level be cooled to this temperature; and the same result might take place with other gases of relatively small volatility which occur in air. This would explain the clouds that have been seen at an elevation of fifty miles, without assuming the possibility of water vapour being carried up so high. The whole mass of the air above forty miles is not more than one seven-hundredth part of the total mass of the atmosphere, so that any rain, or snow, or liquid, or solid air, if it did occur, would necessarily be of a very tenuous description." This is the last that science has said about—

> ". . . the clouds that pass
> For ever flushing round a summer sky."

"CLOUDS" AND THE "SILVER LINING."

THE HUMAN HAND.

IN treating of any part of the body, we may deal with it in one of two ways. We may speak of its uses or functions, its present powers, and its future possibilities—that is, we may treat of it from a *physiological* point of view; or, on the contrary, we may deal with its structure, its variations, and its history—that is to say, we may deal with it *morphologically*. In the present paper this second aspect of the subject will be chiefly dealt with, and a commencement may be made with a short description of the human hand.

Like all similar parts, this may be divided into three regions, the simplest names for which are wrist (*carpus*), palm (*metacarpus*), and digits. Of the digits, or fingers, there are five, all but one of which are provided with three joints (*phalanges*); the single exception is the thumb, in which there are but two joints. The ordinary names for the other digits are (1) pointer or index; (2) middle finger; (3) ring finger—so called as being that on which Christian brides, at any rate, have been in the habit of wearing the marriage ring, and whence, as the beautiful fable reports, a vein goes direct to the heart; (4) little finger (*minimus*). That foot of a verse which is known as the *dactyl*, and which is made up of one long and two short syllables, is so called from the Greek word for a finger. The palm also exhibits the number five, consisting as it does of five elongated and slender bones, terminating in large rounded heads, on which the first joints of the fingers can easily play (Fig. 1).

The wrist itself is short and broad, and in man is made up of eight bones arranged in two rows; on one side it is connected with the bones of the palm, and on the other with the outer bone (*radius*) of the fore-arm, and indirectly with the inner bone (*ulna*). It will not be necessary to give all the scientific names of these, but there are one or two which demand a special notice; and first of all that which is connected with the thumb.* As is well known, this digit is, in ourselves, capable of an extraordinary amount of movement, and by itself might be said to be nearly equal to all the other digits put together; thus, it is capable of movement in two distinct planes: it can move inwards over the palm, and it can also move downwards so as to be set at right angles to the palm and fingers. Such an arrangement has naturally enough excited the admiration, and at times inflamed the reason, of naturalists. The matter has been put in the clearest light by Professor Owen, and we shall do well to quote his words: "Man's perfect hand is one of his peculiar physical characters; that perfection is mainly due to the extreme differentiation of the first from the other four digits, and its concomitant power of opposing them as a perfect thumb. An opposable thumb is present in the hands of most four-handed animals, or *Quadrumana* [the apes, etc.], but is usually a small appendage compared with that of man." It may therefore be supposed that the bone on which this thumb plays is of a peculiar character; and so it is, for instead of having a simple rounded head, or a correspondingly simple hollow to receive a rounded head, it is saddle-shaped on the face to which the innermost bone of the palm—or that for the thumb—is attached. Occupying almost the centre of the wrist, though reaching to the palm, is a large bone, which is almost always known as the *magnum*, or great bone of the wrist;

* Cuvier insisted that the "hand" proper displayed the power of opposing the thumb to the rest of the fingers.

but it is curious to observe, as an example of the history of comparative anatomy, that in most animals this bone is of a relatively inconsiderable size, while it may warn us against the too common error of arguing from what happens in man as to what will happen in the lower animals. Of the remaining six, one, the pea-shaped bone (*pisiform*), does not belong to quite the same series as the rest; while two are connected with the radial bone of the forearm, the boat-shaped (*scaphoid*) bone, and the *semilunar*.

These various bones are moved on one another by a number of muscles, which form the fleshy part of the hand, and these again are roused to activity by nerves, and enabled to effect their work by the supply of nourishment afforded them by blood-vessels. The muscles are arranged in two distinct sets: one, the so-called *flexors*, placed on the palmar aspect, flex or bend the fingers; while others, on the opposite surface, are the *extensors*, which draw the finger-joints back again, or bend the back of the hand on to the arm. It is not possible to give here a detailed account of the distribution of these muscles, but it will perhaps be interesting to explain the anatomical relations which, in the pastime of "Sir Creswell Creswell," prevent the tips of the ring fingers from separating when the middle fingers are flexed. The tendon which goes to the back face of the ring finger gives off two tendinous bands, one for the middle, and one for the little finger; when, therefore, either of these fingers is flexed, the ring finger has its tendon held down, so that its proper action—which is, of course, to extend the ring finger, or bend it towards the back of the hand—cannot be put in use. Neither the nerves nor the vessels can be described here in any detail, though with regard to one of each a word must be said. And first, as to the nerve, which is not only one of those which go to the muscles, but one of those by which we *feel* the action of various influences on the skin of the hand. We all know that when we strike the elbow at a particular point a peculiarly painful sensation is felt in the hand; this, which is due in the first place to that law of nervous action by which irritation of a *sensory* nerve gives rise to a feeling in the parts to which it is finally distributed,* is effected by the course taken by the so-called *ulnar* nerve, which comes very near to the surface at the elbow, and then passes on to the hand, giving off some branches to muscles, and some to the skin. The vessel to which we would refer is that by which we "feel the pulse"; it belongs to that series which carries blood from the heart, or the arteries, and is distinctively known as the *radial* artery; unlike most of that series, it is at the wrist largely exposed, and so forms a convenient and ready method of testing the action of the heart, rising and falling as it does

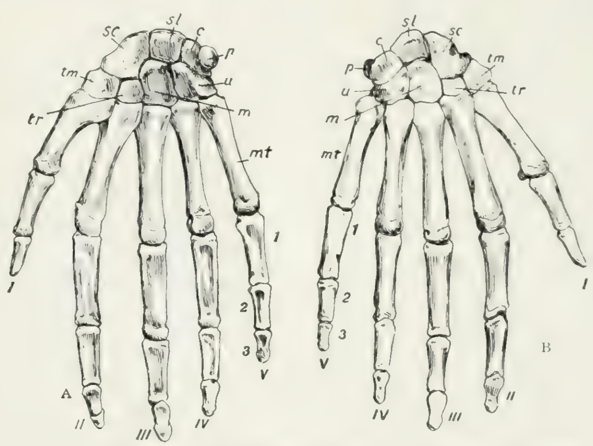


FIG. I.—BONES IN THE HUMAN HAND: A, PALM; B, BACK.

I.—V., the digits; I. being the thumb.
1, 2, 3, the phalanges or joints.
m, magnum; mt, metacarpals; u, ulnar; p, pisiform; c, cuneiform; sl, semilunar; sc, scaphoid; tm, trapezium; trapezoid.

* *See* "Nerves and Nervelessness," CASSELL'S POPULAR SCIENCE, Vol. I., p. 412.

after each contraction of that organ. As to the skin, we need only point out the complete absence of hair from the palmar face, and the comparatively slight extent to which it is developed on the back of the hand ; still, a few words must be said as to the nails. The peculiar points about the nails of man are that they are all comparatively flat, and that they do not in any way seem to afford protection for the ends of the fingers by growing round them, as do the hoofs of the horse and cow, for example. As regards the flattening of all the nails, we must, however, observe that in the orang, the chimpanzee, and the gorilla the same obtains, while in the gibbons it is only on the thumb (and on the great toe) that the nails are flattened. The white part of the nail is known as the *lunula ;* its appearance is probably due to the thickening of the "bed" of the nail at this point and to the less rich supply of blood-vessels, which shine through under the rest. The papillæ which cover the *matrix* or soft skin underneath the semi-transparent horny tissue at this point are smaller and not so muscular as those in the other parts. Among other proofs of the nails being nothing more than somewhat altered parts of the skin is the fact that they are made up, like the scarf-skin itself, of flattened scales, while the younger parts, just like the younger cells of the outer skin, are softer and more rounded. The best proof of all is afforded by some of the frog family, where the skin (*epidermis*) is merely thickened at the ends of the different digits. Instances have been observed of nails growing on the stumps of amputated fingers, but these are not common, and when they do occur the nail is ugly and misshapen.

On account of the striking difference in the powers of the hand and foot in man, as compared with monkeys, the terms *Bimana* (two-handed) and *Quadrumana* (four-handed) have been applied to them respectively ; but with regard to this it must be observed that there are numerous peculiarities which distinguish the hand (Latin, *manus*) and the foot (Latin, *pes*), and that with regard to these points the foot of the ape is as truly a foot as that of man. Again, if the word *hand* is to be taken as meaning merely a seizing organ, then many monkeys might be called five-handed, for their tail is as much of use to them as their hands or feet, and the elephant might at least be credited with a very powerful hand, for its trunk is a most useful seizing organ. The Greeks recognised this, as is shown by their having applied their name for the hand to the trunk of this creature. The difference between man and apes was insisted upon by Blumenbach and Cuvier ; but the sagacity of Linnæus, the veritable father of modern zoology, saved him from such a course, the ill-advisedness of which must strike everyone who has seen, as it has fallen to the lot of the writer to see in the Museum at Antwerp, a man, maimed of both hands, copying with exquisite precision some of the glorious masterpieces which adorn the walls of that building. This artist—he cannot be called this cripple—held a brush between his toes.

Cuvier placed man in a distinct order, to which he gave the name of "Bimana" (two-hands), but modern zoologists prefer to follow Linnæus, who put man into the order "Primates," in company with the "Quadrumana," *i.e.* the monkeys and lemurs. It may be noticed in passing, however, that the four so-called hands of the Quadrumana are not to be compared in point of variety of movement to the highly evolved two hands of the human. The four hands of the monkey are all used for support and locomotion. Man has specialised two of his hands to meet the locomotion and support problem, and has at disposal for other purposes his two "hands."

A word may be said about right- and left-handedness ; for all functions depend

sooner or later on structure, and the "common error," of which a distinguished writer on the hand has spoken, "of seeking in the mechanism the explanation of phenomena which have a deeper origin," cannot be fairly taken as applying to parts which owe all their activity to the supply of blood which they receive either directly or indirectly. The explanation to which the words just quoted referred was that "the superiority of the right arm is owing to the trunk of the artery which supplies it passing off more directly, so as to admit of the blood being propelled more forcibly into the small vessels of that arm than the left." This explanation, indeed, has not much anatomical evidence to support it; but that which ascribes the superiority to the freer supply of the blood to that part of the brain whence messages are sent to the right hand has a strong basis in fact. The question is one which has been much discussed, and it is impossible to give all the views on it, but the ingenious explanation that those who advanced the right side first in battle would be less exposed to fatal wounds is one which it is right to mention. There is a peculiarity in some right-handed persons which is extremely curious: it is this—they always deal cards with their left hand, and that although for other purposes it is just as useless as in most men. Finally, it may be mentioned that an eminent surgeon is reported to have urged on his pupils that they should always *knock on a door with their left hand*—a forcible way of putting the fact that success in surgery will always come most largely to those who are *ambidextrous*. How far right-handedness is due to nature, and how far to education, is a somewhat barren question, as it is obvious that a habit, if practised consistently as the result of education, will come to be brought about by heredity.

Turning now to the lower animals: to learn from them some of the changes which this organ may undergo, and to understand the degree of its perfectness in man, we commence with a few words on the higher apes. It has already been pointed out that the hand of the Quadrumana differs in no essential point of structure from that of the Bimana (man)—it "possesses not only every bone, but every muscle that is found in that of man." The difference lies in the degree to which these are developed; thus, the thumb is in all cases smaller: but this of itself may be an advantage to them, as they use their hands more for climbing than for construction, and it is in those that are excellent climbers or that live always in trees—in such forms, that is, as the American spider-monkeys, the Asiatic gibbons, or the African colobus—that we find the thumb most reduced. But the hand itself is but the terminal portion of an organ—the arm, which, it is to be observed, is proportionately longer in monkeys than in man. This peculiarity is also to be noticed in children as compared with adults. This length of arm seems to be inconsistent with the upright position, but we must remember that the higher apes can move along without the aid of their hands; and although, as Mr. Darwin tells us of the gibbon, it moves awkwardly and much less securely than man, yet when this ape does walk upright it is reported to only touch the ground now and then, just as does a man who carries a stick without requiring the use of one.

It is a general rule in all mammals—that class of the animal kingdom to which man belongs—to have no more than two joints in the thumb, and three in all the other fingers; and this rule applies also to the corresponding parts of the lower limb—the foot: in none of them, any more than in any bird, any living reptile, or any one of the frog class (*Amphibia*), are there more than five fingers to the hand—except, of course, in cases of monstrosity, such as in six-fingered men or women. To the first rule there is but one exception, and that is found among those animals which, though

living in the sea, are veritable mammals, and which, like all others of their class, are unable to breathe the air dissolved in the water, and have continually to come to the surface to respire ; these are the whales. In them the hand does indeed seem to be very remarkably metamorphosed ; seen from the outside, there is no indication of the presence of separated fingers, not even the slight one that could be given by the presence on it of claws or nails : it is converted into a flipper-like paddle, set close to the body. When, however, the skin and muscles are removed, it is seen to possess wrist, palm, and four or five fingers, just as in man, but the joints of these fingers are not limited to two or three, and there may even be as many as twelve or thirteen phalanges in some of the digits. In those whales that develop whalebone in the place of teeth many of the parts of the hand never become bony at all, but remain cartilaginous ; the joints, too, between the different parts are not developed, and the only power that the hand has of yielding or bending is such as it can gain from the elasticity of cartilage. To show how variable the number of the phalanges is, it will be sufficient to state how they are set in the two forms of whales best known to most of us. The porpoise : this animal, which is sometimes seen even as far up the Thames as London Bridge, has two phalanges in the thumb, eight in the next finger, and then six, three, and two ; in the common dolphin there are two, ten, seven, three, and one phalanges, while in the round-headed form there are as many as fourteen joints in the index finger (Fig. 2). Of the mammal class there is yet another group which is purely aquatic, and, speaking generally, this mode of life is about their only point of similarity to the whales. Of these, the *Sirenia* (or mermaids), we now only know two living forms ; a third form (*Rhytina Stelleri*), which is related to the manatee and dugong, has died out. This *Rhytina*, discovered by Behring and Stelle when their ship was wrecked upon Behring Island in 1741, and described by the latter, was said to be very numerous in the Northern Pacific at that time. Incessant hunting soon thinned them down, and finally they disappeared, probably by the middle of the last century. Owing, probably, to their mode of life, these animals have the hand converted into a paddle, and no signs of separate fingers can be made out in the living form ; but the inspection of their skeletons reveals the presence of a hand which, by the possession of five digits and the ordinary number of phalanges, agrees essentially with that of man.

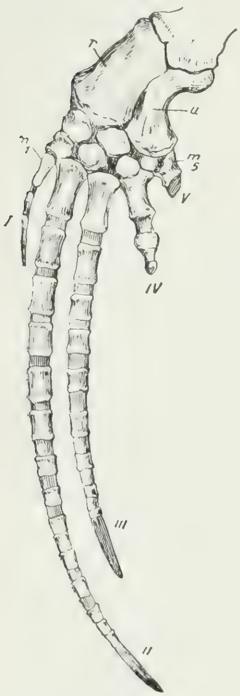


FIG 2.—HAND OF ROUND-HEADED DOLPHIN.

I–V, digits; r, radius; u, ulna; m^1, m^5, 1st and 5th metacarpals.

There are 14 joints in the index finger. Compare with the human hand, which has 3.

There is another group of mammals which, unlike most of their kind, do not walk on land, but are flying animals ; these are the bats (*Chiroptera* — wing-handed animals). Figs. 3 and 6 will show better than any description the difference between the arms of these animals and the arms of the birds who are, amongst vertebrates, the flying animals *par excellence*. It is, therefore, necessary only to point out that the surface required to support the animal in the air, and which is formed by outgrowths of the skin itself, is chiefly provided for by the great elongation of the bones of the hand ; the thumb is not included in

this fold of skin, but forms a claw by which the animal may support itself on trees and bars. The metacarpals (or bones of the palm) are greatly elongated, and, as a rule, are succeeded by *two* phalanges, which are also very long and very slender. It is striking to observe that, notwithstanding the extreme length of the bat's hand, the number of phalanges should be even less than in man. The other members of the mammalia which are able to fly—the flying lemur of the Indian Archipelago, the flying squirrels, and the flying phalangers of Australia—are not aided by any modifications of the hand, nor is their flight long continued or steady.*

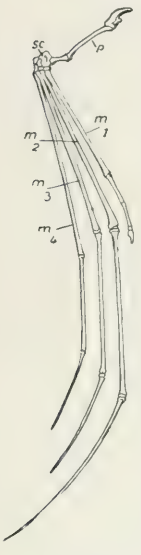


FIG. 3.—HAND OF BAT.

p, pollex; sc, scaphoid; m^1–m^4, the 4 metacarpals.

As we cannot deal with all the marvellous variations in the structure of the hand which are seen in mammals, we will pass on to a group in which the reduction of the digits affords one of the easiest, as well as one of the most instructive, series of changes which can be found in the whole realm of comparative anatomy: these are the hoofed animals, or *Ungulata*, of which there are two series, markedly distinguished by many anatomical differences. For our purpose the most important is that in one the number of digits is always even, and in the other always odd; to this, however, there are two curious exceptions. To the one group belong the tapirs, rhinoceroses, and horses; to the other, sheep, oxen, deer, goats, and pigs.

But with regard to the tapir, that curious, old-fashioned looking animal which is now found living only in such widely distant regions as South America and Sumatra, we have to observe that there are four toes on the hand, though only three on the foot, and that of these four toes the outer one has ceased to touch the ground. The other exception is also found in a South American form—the peccary; but the peculiarity here lies in the foot, in which there are only three, and not, as in the hand, four toes. Of all these beasts the most remarkable is the horse, in which only one digit is developed and touches the ground. The bones of this member are greatly elongated and are very strong; the wrist, or carpus, is even here made up of seven bones, the largest and broadest of which is the one that we have already heard about—the *magnum;* in the metacarpus there are two narrow bones, one on each side, which represent the second and fourth metacarpals; these flank a large and long bone—the highly developed third metacarpal; and this, again, is succeeded by three phalanges, the two lower of which are broadened out, and the last one most remarkably so. Owing to the

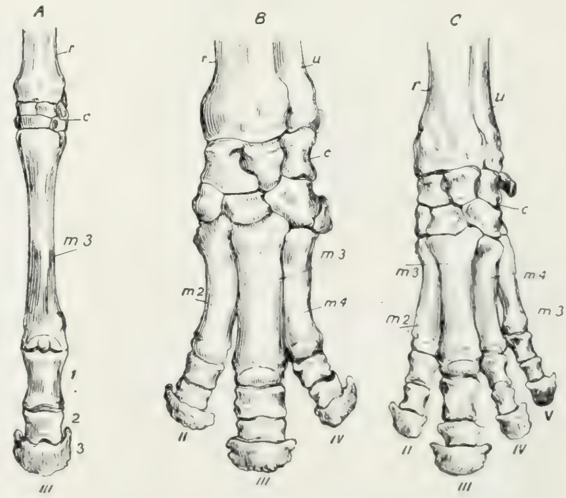


FIG. 4.—HAND OF HORSE (A); RHINOCEROS (B); AND TAPIR (C).

II.–V., digits; r, radius; c, carpus; 1, 2, 3, phalanges or joints; m^2–m^4, metacarpals.

* *See* "Flying Reptiles," CASSELL'S POPULAR SCIENCE," Vol. I, p. 365.

length of the bones below the carpals, the wrist gets to be so high from the ground that it ordinarily goes by the name of the "knee" (Figs. 4, 5, and 9).

In the rhinoceros three toes touch the ground, but the middle one is larger than those on each side; while, as we see in the above figure, the tapir still retains its fifth digit, shortened a little though it be. A still more instructive series of changes has been made out by the aid of a study of some fossil forms which were, without doubt, closer allies to the horse than are either the tapir or the rhinoceros. These are known as *Hipparion* and *Anchitherium.* When we compare—as by the

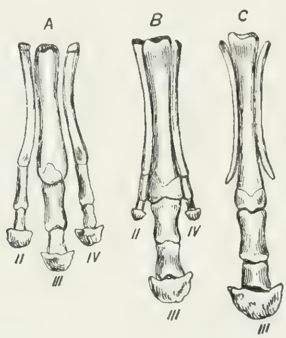


FIG. 5.—FOOT OF *ANCHITHERIUM* (A); *HIPPARION* (B); HORSE (C).
II, III, IV, digits.

aid of the subjoined figure (Fig. 5) we are enabled to do—the hands of these three forms, we observe that the toes get shorter and shorter until at last the digits cease to be developed. Nor is this all the story; to explain which we must say that the later periods of the history of our earth are, or may be, divided into five: Early Eocene, Later Eocene, Miocene, Pleistocene, and Existing. Now the modern horse is only known in the last two of these periods, *Hipparion* in the third and fourth, and *Anchitherium* in the second and third. A still earlier form, to which the ever illustrious Cuvier gave the name of *Palæotherium*, has not been found in any layers which belong to a later period than the Later Eocene; in this form, again, there were only three digits. In addition to this, we have to observe that the rhinoceros has been found in Indian

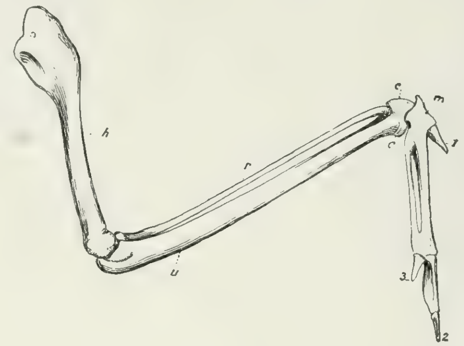


FIG. 6.—BIRD'S ARM.
h, humerus; r, radius; u, ulna; c, carpus; m, metacarpus; 1, 2, 3, digits.

deposits of the Miocene epoch, and the tapir in the deposits of the same period near Auvergne. We see, then, a series of changing forms going hand in hand with changes in the earth's surface, while the scarcity at the present day of the almost unchanged tapir and rhinoceros, and their greatly restricted range, are full of significance as to the necessity of adapting oneself to circumstances when one is desirous of continuing to exist.

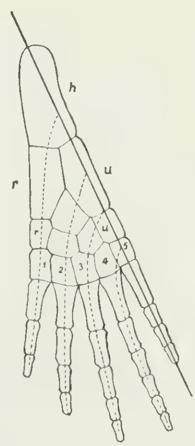


FIG. 7.—FORELIMB OF AMPHIBIAN.
h, humerus; r, radius; u, ulna.

Did space permit, we might enlarge at greater length on this most interesting and instructive subject, and might draw many examples from the even-toed forms, but we must content ourselves with attracting attention as briefly as possible to the studies of a Russian anatomist, who illustrated the reality of the great republic of Science by drawing his examples from specimens in the British Museum. This gentleman has, by the study of fossil forms, shown that in some of these the median

metacarpals did not seize on the outer carpal bones when the digits with which these bones articulated dropped away; and that *such forms have disappeared.* In others, again, such as the deer or the ox, the carpal bones became connected with the remaining and median metacarpals, so that in them, just as in the horse, the number of bones in the wrist is not very greatly reduced, and "a better and more complete support for the body" is thereby gained; *such forms have not disappeared.* To these two modes Dr. Kowalewsky has given the appropriate names of *adaptive* and *inadaptive* modifications.

It is impossible to speak of the other mammals; and we must now begin to draw our notes to an end by giving a rapid sketch of the changes in arrangement which convert the typical five-fingered hand into part of a wing. In very nearly all birds there are three digits, one of which is the thumb, which does not here disappear so readily, as it were, as it does in so many quadrupeds. In many birds this thumb retains a claw, in some the index finger does so also, but in no known case is there a claw on the third (*median*) digit; the thumb is connected with a short metacarpal; the other two bones of the palm are very largely fused into one bony mass; and the bones of the wrist are reduced to two (Fig. 6).

We come now to the final question—What is the meaning of these relations common to all hands? Why is the number five so constant and so characteristic, and yet why is it at times so extraordinarily modified? To answer these questions would be to write a chapter in the history of creation; but at the same time there are a few facts which cannot be passed over. When we examine the arm and hand of one of the simplest of the five-fingered forms—a representation of which is here given (Fig. 7)—we find (1) a single bone, (2) two bones, (3) a set of ten bones, (4) a set of five bones, and (5) five digits with a number of bones in each. Along this we can draw one straight line, and on one side of this four other lines, passing out like rays from a central stem. It is clear that the rays of the other side have been lost if the hand of the Amphibian is really based on a "type" of such a kind at all; whether it is so or not, it is curious to observe that such a "type" does exist in a remarkable form (*Ceratodus*), which was discovered in 1870 in the rivers of Australia, and of

FIG. 8.—FORELIMB OF CERATODUS.

This curious Queensland mudfish is known locally as "Barra munda." It is about 6 feet long.

which an instructive figure is given (Fig. 8).

We have now traced the hand of man through various series, and have seen how, under varying circumstances, its structure becomes altered; yet, with all these changes, we have seen striking points of similarity in all, and we have lastly been able to see a possible origin for all these forms; so that we have had illustrated to us the two chief modes by which peculiarities of structure are brought about — "the influence of heredity," by which the "typical form" is preserved, and the influence of surrounding circumstances and of changed habits of

life, which have effected the most wonderful changes in arrangement within a comparatively restricted area of structure.

When the "extremes" only of these modifications are taken, it is difficult to see any connection: hence the necessity for the consideration of the intermediate links. It is only by comparing these latter with the extremes—the marvellous human hand on the one side, and the equally marvellous "flipper" of the whale on the other—that a true relation can be established.

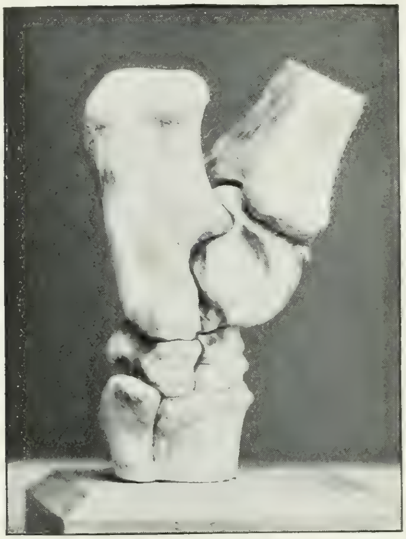


FIG. 9.—HOCK BONES OF HORSE.

THE AURORA BOREALIS IN ITS FULL GLORY.

THE LONG POLAR NIGHT WOULD BE DISMAL IN THE EXTREME WERE IT NOT FOR THE MAGNIFICENT DISPLAYS OF THE NORTHERN LIGHTS

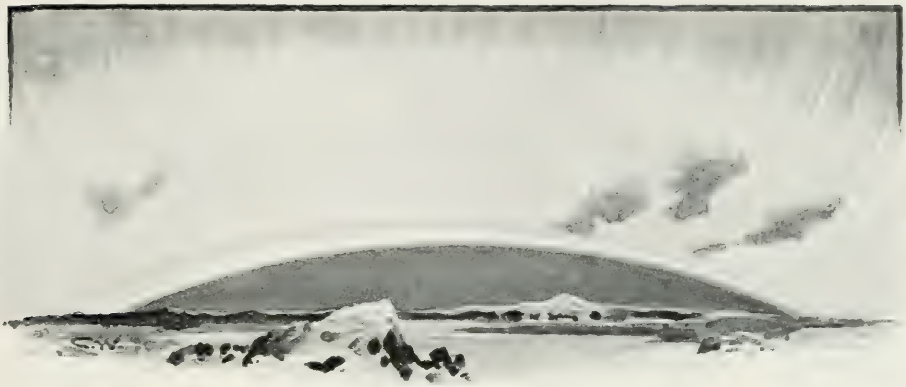


FIG. 1.—THE LOW AURORA.

THE NORTHERN LIGHTS.

SOME of us have seen, even in these latitudes on certain rare occasions, beautiful arches of light stretching across the heavens, rapidly changing in form and colour, with now and again bright rays flashing out perpendicularly from them (Figs. 1, 2, 3, 6, 7, 8, and 9).

To observe these phenomena, however, in all their beauty, we must pay a visit to higher latitudes,* where they are seen much more frequently, and in far greater splendour.

These appearances are most generally known as the Northern Lights, the Merry Dancers, or the Aurora Borealis, owing to the fact that the high northern latitudes have been much more visited than the southern. The same phenomena, however, are to be seen as we go southwards, and so they are sometimes spoken of under the name of the Aurora Australis. The most popular name has been chosen for our title, though perhaps the most appropriate one that has been applied to them is that of Aurora Polaris. As few of those who read this will ever have the opportunity of actually visiting either the northern or the southern polar regions, let us imagine ourselves for a brief season to be upon the deck of a vessel far away in the north—let us say in the autumn, just before the approach of the long Arctic night. As we glance round, all looks cold and bleak. There is light enough for us to see on every hand the fantastic forms of the icebergs looming up in the darkness. We hear the grinding of the bergs together, and cannot suppress an uncomfortable feeling as the contingency presents itself to our mind of the ship running aground between two of those huge floating ice islands.

As we look, the scene changes as completely as though a magician's wand had transferred us to one of the jewelled palaces of the "Arabian Nights." We see arches of light stretching across the heavens from east to west—sometimes remaining stationary, and sometimes moving slowly towards the south. Rays

* They may be observed in greater perfection in moderately high latitudes than in the extreme north. For instance, few auroral displays were witnessed at Floe Berg Beach, in Smith's Sound (lat. 82° 27′ N.) during 1875-6, when the *Alert* wintered there. The Arctic auroras are also of a pale straw colour, reflecting more light than those one sees in the North Sea, where the usual phenomena witnessed consist of a brilliant arch extending from one horizon to another, with red and yellow flashes. "I remember, on returning from Beechy Island in the month of September, admiring the North Sea aurora as a more showy phenomenon than the modest but beautiful northern lights that we had been accustomed to see during our two winters in Wellington Channel." (*Captain May, R.N.*)

of light shoot out perpendicularly from the arches, and if the arches are below the horizon we only see these rays, which, though really parallel, often appear as an effect of perspective to meet in a point of the zenith. These rays very seldom remain stationary, but shoot upwards towards the zenith, at the same time moving eastwards, often with a tremulous, snake-like motion from end to end, till sometimes they cover the whole sky.

If now we turn our eyes from this magnificent light to look down again upon the surrounding bergs which just now looked so weird and gloomy, we can scarcely believe that they are the same, for now they throw back to us in a thousand colours the light that flashes on them from above, and the peaks and pinnacles of the bergs appear to be set with jewels of the most varied hues and the most dazzling brightness.

The aurora appears in the most varied forms and patterns, in one of the most beautiful of which, though seldom seen, the rays seem to hang from the sky in folds like a mantle (Fig. 2).

FIG. 2. "THE RAYS SEEM TO HANG . . . IN FOLDS LIKE A MANTLE."
This fine aurora was seen at Bossekop, January 6th, 1839.

It is at present rather doubtful whether the auroral displays are or are not accompanied by any sound. Many observers have asserted that during the duration of an aurora they have heard crackling and hissing sounds; but, on the other hand, some of the most eminent polar explorers* have listened in vain for these sounds, and have given it as their opinion that what was heard was merely the breaking up of the ice and the grinding of the icebergs.

Having now in our mind the appearance of these northern lights, we will repeat a well-known laboratory experiment (Fig. 4). We take a glass tube,

* Among others, Sir George Nares and his companions, who also considered that the faint auroral displays seen from their winter quarters were "in no way connected with electrical or magnetic disturbances."

partially exhausted of its air. Platinum wires pass through the ends of the tube, and we attach the terminals of a powerful induction coil, but as yet we perceive no result. We now begin to exhaust the air from the tube, and as the exhaustion goes on we soon see a soft, tremulous light beginning to play about the ends of the tube; and this, when the air is sufficiently rarefied, gradually extends right through the tube. As we continue the exhaustion, these phenomena will be reversed, the light gradually dying away as the exhaustion increases. We shall at once perceive how very much this resembles an aurora on a small scale, and so we have electricity suggested to us as the agent which produces the aurora.

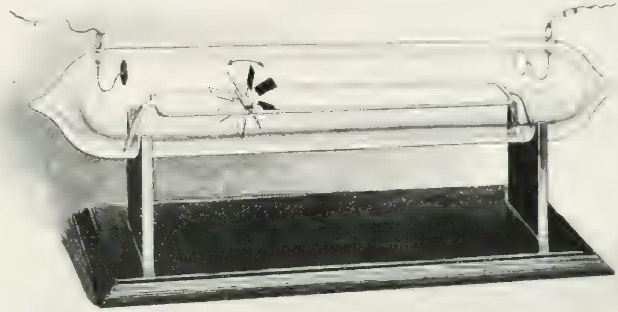


FIG. 4.—A PROBABLE EXPLANATION OF THE CAUSE OF THE NORTHERN LIGHTS.

A glass tube, fitted with platinum wire terminals, is partially exhausted of air. The terminals are next attached to a powerful induction coil. As the tube is still further exhausted of air, a soft, tremulous light may be observed at the two ends.

Now, before we pursue further the path of inquiry which this analogy opens up to us, it must be pointed out that when we speak of magnetism or of electricity we are really speaking of the same agent. We do not know exactly what change a piece of iron or of steel undergoes when it is magnetised by being brought under the influence of an electric current; but we know that a coil of wire, with a current passing through it, behaves in every way just like a magnet.

FIG. 3.—THE ARCH AURORA.

Compare with the bow aurora in Fig. 1.

Now, if we take a magnet of any form, it will be in the same way surrounded by a field of force, and the shape of the lines of force, and the manner in which the intensity varies from point to point, will depend on the form of the magnet.

The lines of force in the neighbourhood of a single pole, or of two poles respectively, may easily be shown by placing a card above one of the poles of a bar magnet, or over the two poles of a horseshoe magnet, and sprinkling iron filings upon it, when they will range themselves along the lines of force, which in the first case will radiate from the single pole, and in the second case will arrange themselves in a series of curves, which are quite distinct and very beautiful in form.*

The earth is a great magnet, and the direction of the line of force through any

* *See* "The Wizard Electricity—I," CASSELL'S POPULAR SCIENCE, Vol. I, p. 49.

point on its surface is easily found in the following manner.

We first take a needle, and suspend it in such a manner that when magnetised it will turn freely in a horizontal plane. If now we take a line on the earth's surface through this point in the direction in which the needle comes to rest, we get what is called the magnetic meridian at that point; and the angle between this and the geographical meridian is called the *declination*.

We next balance a steel needle very accurately upon a horizontal pivot, and place it so that it can turn freely in the vertical plane passing through the magnetic meridian. We shall find in these latitudes that, when magnetised, the north-seeking end of the needle will point downwards at a considerable angle to the horizontal, which is called the angle of *dip*, the needle being called the dipping-needle.

The direction of the needle now gives us the direction of a line of force, and we find that the lines of force start from near the poles and rise to a great height above the surface of the earth near the equator. Now, the rays which are seen in the aurora are always parallel to the dipping-needle—*i.e.* to the magnetic lines of force—and this is another indication that electricity is in some way or another the agent in auroral displays.

The rising upwards of the lines of force as they approach the equator gives us one reason that auroras are seen more often, and to greater advantage, as we approach the poles, for the lines of force rise to such a height that, even if the display took place so high up, it would become more and more difficult, and at last impossible, for us to see them. Most probably, however, the displays would not take place at these great heights, owing to the extreme rarefaction of the atmosphere—just as we found, in the case of the exhausted cylinder, that when the exhaustion was carried beyond a certain point the discharge took place with continually decreasing intensity, and finally ceased altogether.

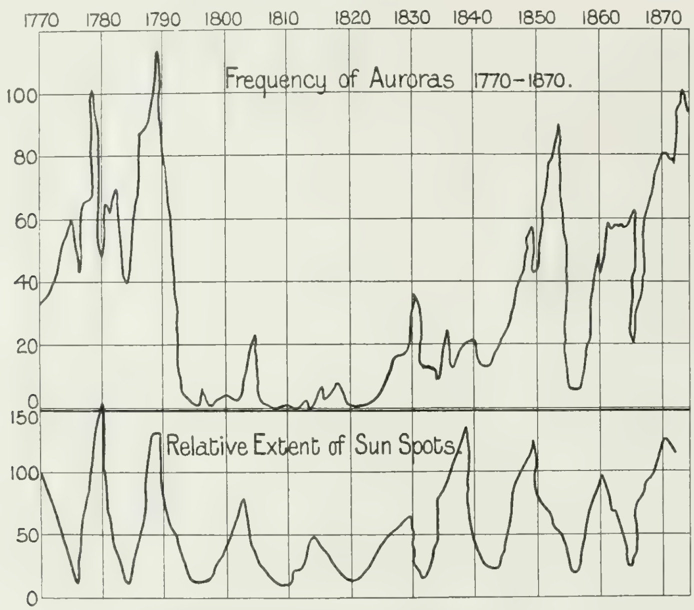


FIG. 5.—FREQUENCY OF AURORAS AND SUN SPOTS: A COMPARISON.

Probably some readers have noticed that when the current from a powerful

induction coil was being sent through the vacuum tubes, a tendency to stratification, or the formation of striæ, was distinctly observable. With the best apparatus, and in the hands of careful scientific workers, these striæ can be obtained with a perfect distinctness and uniformity, looking like a row of discs placed at regular intervals one in front of the other, and can be made to remain stationary or to move slowly or rapidly along the tube, by altering the electrical resistance of the circuit or the speed of the contact-breaker. These striæ are exactly analogous to the arches in the aurora, for the arches, as they appear to us, are in reality circles concentric with the magnetic pole.

Again, the intensity of the magnetic force at any place, the declination, and the angle of dip are subject to variations, some of which are periodic—diurnal, annual, and some of longer periods; and others are sudden and irregular, and brought about in a manner about which we know very little, though comparatively recent researches have shown us that these sudden irregular disturbances, or magnetic storms, as they are called, are very closely connected with the solar storms which show themselves to us as sun spots, and with the nature of which we are gradually becoming acquainted through the wonderful revelations of the spectroscope. We should therefore expect the auroral displays, if really magnetic phenomena, to show some connection with these magnetic storms; and as a matter of fact we find that auroras are only to be seen during the prevalence of these magnetic storms.

FIG. 6.—A BRIGHTLY RAYED AURORA.
Seen at Brevillepont, September 26th, 1731.

The very close relationship between the number of sun spots and the magnetic storms is shown in a graphic manner in Fig. 5. The rising and falling of the lines indicate the increase and decrease in the solar and magnetic storms.

The magnetic storms are not by any means only to be detected by means of special instruments for observing changes in intensity, declination, and dip, or, as

we usually say, changes in the magnetic elements; for when these storms are at all considerable strong currents are produced in the telegraph lines, and in some instances the telegraph operators have been obliged to cease working the line during the prevalence of the magnetic storm.

Auroral displays usually take place at a great height—sometimes as high as 300 miles—while their average height is over 100 miles. At such heights the air must be extremely rarefied, and we should be disposed to expect that the electric discharge could not take place through it.

An experiment due to Lemstroem reproduces the aurora on a small scale. A number of tubes containing rarefied air are arranged so that they are presented towards a metal ball attached to an electrical machine. The ends of the tubes, which are turned away from the ball, are connected with the earth.

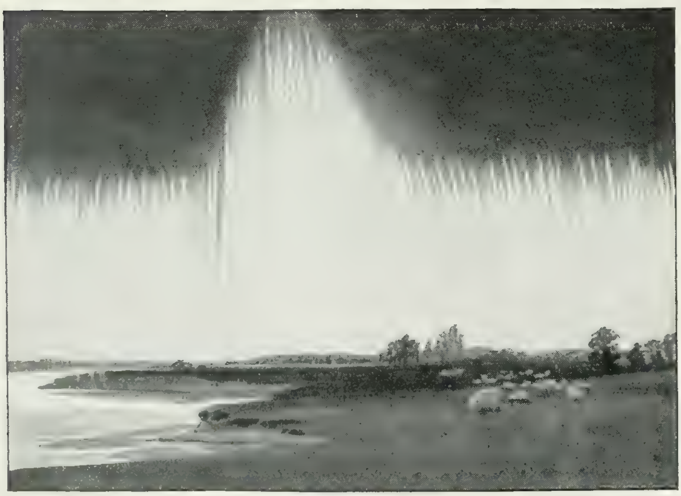


FIG. 7.—ANOTHER FORM OF AURORA.

Here the rays rise high above the horizon, and appear to be almost parallel to each other; or, at the most, they describe very gentle curves.

When the machine is worked the tubes are lit up with glowing incandescent gas, while the air between the tubes and the ball does not emit any light. The experiment shows that the passage of electricity through rarefied gas will cause the latter to become luminous, although no such effect is visible when the gas is at ordinary pressure. The air in the higher regions is rarefied, and it is thus reasonable to think that the passing through it of electricity may be the origin of the aurora. Whence, then, does this electricity come, and how does it come?

Great advances in the knowledge of what happens when electricity passes through rarefied gases have been made, as the result of the researches of J. J. Thomson, Röntgen, Oliver Lodge, and Crookes.

Crookes found, on experimenting with highly exhausted tubes,* that on attempting to pass electricity through the tube there were rays proceeding from the negative electrode—that is, the piece of wire by which the current should leave the tube. These rays were explained by the discoverer as being negatively charged particles of matter in a form that was neither solid, liquid, nor gas. This theory was scouted at the time, but to-day it is respected. Crookes showed the passage of these electrical particles by arranging a miniature railway inside one of his exhausted tubes. Resting on the "rails" was a light axle with vanes. The bombardment on these vanes caused the axle to roll along. These rays, which are called *cathode rays*, have two remarkable peculiarities:—

1. They are attracted by a magnet held near the tube.
2. When they pass through a gas they cause it to glow.

* *See* "What are the X-Rays?" CASSELL'S POPULAR SCIENCE, Vol. I., p. 73.

If there are at any time cathode rays in the higher regions of the earth's atmosphere, we can see that they may cause the aurora, for, passing through the rarefied air, they will render it luminous, and as the earth is a magnet they will be attracted, and so will form the auroral "arches."

This explanation seems to imply that electricity flows to the earth from regions beyond, and that, consequently, sun, moon, and stars are connected with each other and our earth by an electric conductor—a condition which is difficult of con ception. Yet the close relation between the terrestrial magnetic storms and the prevalence of sun spots shows us that some such communication must exist, and other researches tend towards the same result.

To explain the transmission of light on the now universally received undulatory theory, we have to assume the existence throughout known space of a medium capable of transmitting light-vibrations.

Again, many electro-magnetic phenomena may be explained in by far the most natural way on the assumption that when different bodies are acting electrically upon one another there is an actual transmission from one body to another of mechanical action by means of a medium occupying the space between them. Now, it would be a most unphilosophical proceeding to fill space with a new medium whenever any new phenomena are to be explained; but if, on the other hand, the study of two different sets of phenomena has independently suggested the idea of a medium, and if the properties which must be ascribed to the medium in order to explain one set of phenomena are found to be identical with the properties which must be

FIG. 8.—AURORA OBSERVED AT ORLEANS, FEBRUARY 4TH, 1872.

ascribed to it in order to explain the other set, then the evidence for the existence of the medium is considerably strengthened.

Now, in the case in question we have the means of determining, independently from the two sets of phenomena, the rate of transmission of a disturbance, which can be directly observed in the case of light, and which can also be calculated from electro-magnetic experiments. As a result, we are driven to the conclusion that light and electricity are transmitted by one and the same medium. This medium is the ether, which must be nearly weightless and perfectly elastic, and, moreover, cannot be contained in any receptacle made by man, for all matter seems permeable by ether.

Recent investigations make it probable that the last word on the explanation of the northern lights will come from the ether theory. Indeed, this idea promises to be the foundation of all scientific

explanations, for modern science holds not merely an ether theory of light and electricity, but *an ether theory of the universe*, even to the extent of admitting that the old alchemists were possibly right after all—that all matter is made out of the same stuff: ether.

If we break a fragment of common salt, and select one of the tiny pieces, and smash that into still smaller portions, we shall, in our imagination, eventually reach a stage when further subdivision is unthinkable. We should thus be thinking of the smallest possible particle of common salt. This tiny fragment is called a *molecule*. Chemists teach us that this molecule of salt is compound—that is, contains two substances: a metal *sodium* and a gas *chlorine*. The particle of sodium which is contained in a molecule of salt is called an *atom*, and until quite recently it was held that the atom is simple, indivisible, and the most minute thing in the universe. Following Professor J. J. Thomson, scientists now hold that the atom is gigantic in size when compared with particles contained in it. Thus an atom of mercury is believed to contain 100,000 of these smaller bodies called *corpuscles* or *electrons*, and still there would seem to be room to spare.

FIG. 4.—SERPENT AURORA.

All atoms contain "electrons," the number of electrons differing with the kind of atom; but all electrons are the same, whether they are in an atom of iron or in an atom of oxygen. If there is nothing in an atom but electrons (and this is not quite certain yet), then all atoms—and consequently all molecules, and therefore all bodies—consist solely of a collection of electrons. What, then, are electrons? And, startling as the answer may seem, this conclusion is irresistible, that electrons are *centres of strain*, or *whirlpools of ether*, and a body is electrified if it has not its normal number of electrons in its atoms. One remark-

able fact about these electrons is that they can be shot out of the atom to which they belong, communicating an electric charge to a body on which they fall. This electric radiation is still being studied, and it would seem that in some cases actual atoms are propelled, and in others only the electrons are shot across space. Certain rare elements—especially *radium*—have this property to a remarkable degree, but it is probable that the same action is proceeding with all substances. Hot bodies exhibit electrical radiation markedly, and it is but an easy step from this observation to a theory of the northern lights. The sun is always pouring forth myriads of these electrical particles, and of these some are shot across space towards the earth. The magnetic force of the earth directs and bends the radiant stream which glows in the upper regions of the air, and produces the beautiful phenomenon which is the subject of this article.

FIG. 10.—AN AURORA BROKEN UP BY STORMS.

THE HUMAN BRAIN.

FROM A PHRENOLOGIST'S POINT OF VIEW.

By BERNARD HOLLANDER, M.D.

THE brain, that part of the nervous system contained within the skull, consists of an inner white and outer grey substance, the former being composed of nerve-fibres and the latter of nerve-cells.* In and through this superficial grey matter, or *cortex* of the brain, all mental operations take place. Organic life, nutrition, circulation, excretion, secretion, motion—in fact, all vital functions — can be carried on without the cortex of the brain; but the manifestation of the intellectual and moral powers, the affections, and propensities or instincts of self-preservation, cannot take place without it. Provided that the cortex of the brain be not affected, all the other portions of the system may be diseased, or separately destroyed; even the spinal cord may become affected without the mental functions being impaired. Of course, if the heart, the *medulla oblongata*, or some other vital part be injured, death will precede any such experiment. If, on the other hand, the superficial grey matter of the brain becomes compressed, irritated, injured, or destroyed, the mental functions get partially or totally deranged, or become wholly extinct. When the compression of the brain is removed—as in the case of an indented skull, or a tumour—or the extravasated blood or accumulated pus is taken away, or the inflammation allayed, consciousness and the power of thought and feeling return. We think and feel, rejoice and weep, love and hate, hope and fear, plan and destroy, trust and suspect, all through the agency of the brain-cortex. Its cells record all the events, of whatever nature, which come within the sphere of existence of the individual, not merely as concerns the intellectual knowledge acquired, but likewise the emotions passed through and the passions indulged in.

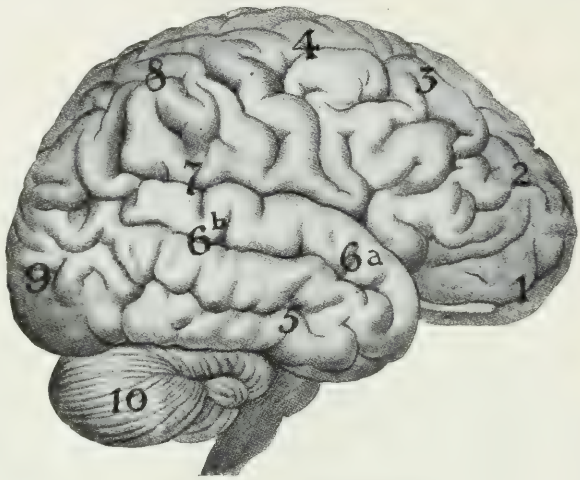


FIG. I.—THE HUMAN BRAIN.

Frontal Lobe	1. *Perceptive powers*	*Intellect.*
	2. *Reflective powers*	
	3. *Ethical sentiments*	*Moral Sense.*
	4. *Religious sentiments*	
Temporal Lobe	5. *Instinct of self-preservation*	*Propensities.*
	6a. *Hoarding instinct*	
	6b. *Secretive instinct*	
Parietal Lobe	7. *Sentiment of fear*	
	8. *Egotism*	
Occipital Lobe	9. *Affections*	
Cerebellum	10. *Libido sexualis.*	

Irritation and mutilation of the brains of living animals—on which much of our modern brain physiology is based—can throw no light on the *mental* aptitudes and dispositions of man, nor will the

* For the purposes of this short sketch, we may neglect the cerebellum and smaller ganglia at the base of the skull, and confine ourselves to the cerebrum alone, *i.e.* the brain proper.

most scrupulous examination of the *neuron*, or brain-cell, reveal the thoughts or feelings which are its function. The phrenologist needs more than an acquaintance with the anatomy and physiology of the brain, as obtained by the vivisection of animals. He must have a perfect acquaintance with human nature, and the intellect and character of men in all walks of life. Anatomists and physiologists study the structure of the brain; the phrenologist studies the motive power. His is the science of *human life*, not merely the science of motion and sensation. The phrenologist ought to be a man of learning; the popular self-styled "professor" is in the same position as the nostrum vendor compared to the qualified physician.

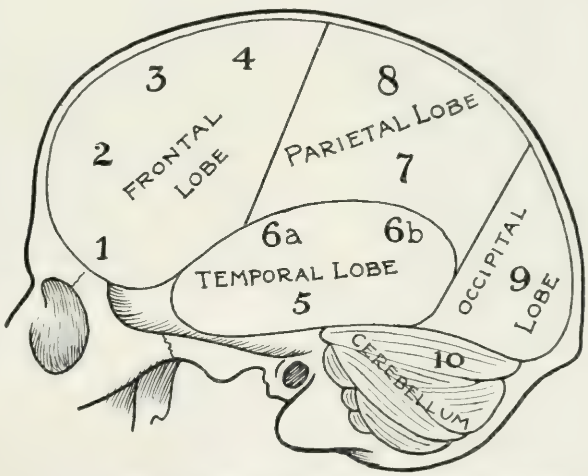


FIG. 2.—THE RELATION OF THE BRAIN TO THE CRANIUM.
See the references to Fig. 1.

Though the brain may be represented as a unit, yet it contains innumerable centres, each with a different function. These centres represent organically every minute detail of knowledge and experience; they register every definite observation and thought, and every process of reasoning with which the individual has at any time made himself familiar; they represent every sentiment and emotion, every affection and passion, and, indeed, every one of those mental processes which are needful for the display of what constitutes human character. All the fundamental kinds of psychical activity are carried on in more or less distinct parts of the cerebral hemispheres. There is the same order in the organisation of the brain as in every other organ, the same physiological division of labour in which all organisation consists.

The brain is more complicated, and the convolutions more distinct and numerous, as we ascend the scale of the animal kingdom. The essential differences obtaining in the structure of the head correspond to decided differences in its functions, and the complexity of the structure is proportionate to the number of aptitudes and propensities displayed. Were the brain a single organ, all species of animals would have the same kind and number of instincts; whereas members of the same species possessing the same primary mental powers manifest them in varying degree owing to the difference in the development of various brain centres. Thus, men possessing first-rate talents of a certain order are sometimes perfectly insignificant in every other respect. Genius is in well nigh every instance partial and limited to the exaltation of a few mental powers, which could not be the case were the organ of mind single. Prodigies are quite as childish as the average young human being in everything but the talent by which they are particularly distinguished.

There are no two skulls nor two brains alike in their configuration; nor are the characters of any two individuals found exactly to correspond. There is a natural inequality in men, and this difference in character distinguishes them from their very childhood.

The existence of such evidence as has been adduced by the author in his work on "The Mental Functions of the Brain,"

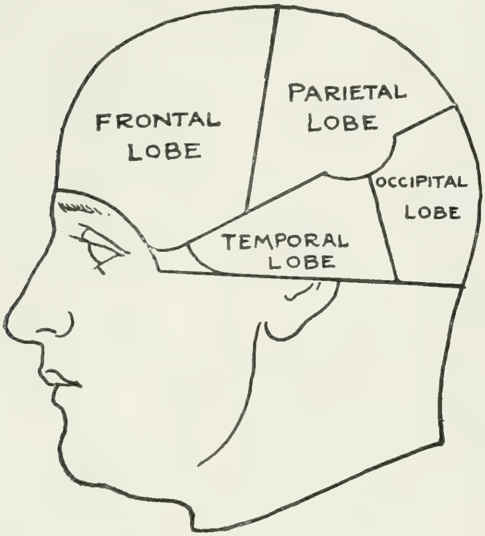


FIG. 3.—THE RELATION OF THE LOBES OF THE BRAIN TO THE SURFACE OF THE HEAD.

to the effect that injury to the head affects one or more of the mental powers, according to the locality on which it was inflicted, while in other respects the individual remains perfectly sound, can only be explained on the principle that the several portions of the cerebral hemispheres have different functions allotted to them. Thus, injury to the brain in the lower parietal region leads to melancholia in different degrees; and injury to the middle temporal region to a manifestation of irascibility, which may end in violent mania, and so on. When the effects of the injury are removed, in such wise as by lifting up an indented bone, the patient recovers his mental equilibrium. Similarly it has been observed that irritation of the frontal cells is characterised by an acceleration of the intellectual processes of perception, association, and reproduction, giving rise to a rapid flow of ideas; and that softening of the same part leads to dementia; whereas irritation of the parietal, occipital, and temporal areas affects chiefly the emotions and propensities, often leaving the intellect quite unclouded. In certain forms of poisoning, too—such as by alcohol—the highest mental powers are paralysed first, thereby depriving a man of the controlling power over his natural tendencies. Hence some intoxicated men become dejected, others gay; some talk foolishly, others are eloquent; some become effusively benevolent, others furiously homicidal, and so on. All these facts point to there being a congeries of centres in the cortex of the brain, not merely for the purely intellectual operations, but also for the emotions and propensities.

In favour of there being distinct centres in the brain is furthermore the fact of the front and the back of the brain having different arterial supply, and, lastly, the observations of numerous investigators show that certain regions of the cerebrum are distinguished from other regions by broad differences in structure.

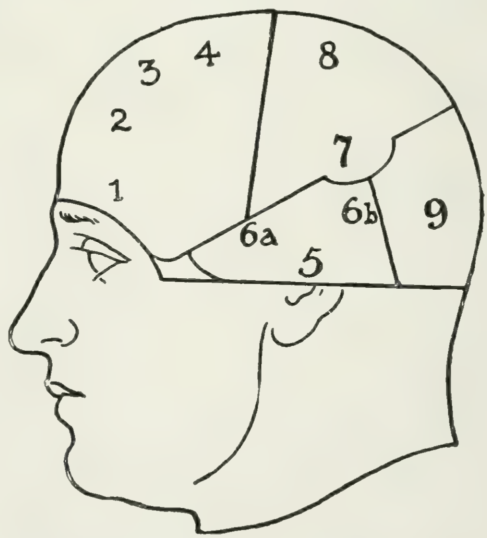


FIG. 4—THE RELATION OF THE LOBES OF THE BRAIN TO THE SURFACE OF THE HEAD.
See the references to Fig. 1.

These structural differences must be correlated with some difference of function. The group of cells whose function is purely intellectual cannot possibly have

the same construction as a group of cells whose function is purely emotional. The two may be united by association fibres, so that one may rouse the other; but the function of each group of cells must be distinct. Though we may speak of a centre, it is understood that, as there are two hemispheres of the brain, every centre is twofold, and to this fact may be due those few instances in which a particular centre has been injured or destroyed without a loss of any mental power being discoverable.

FIG. 5.—SKULL OF A VIOLENT CRIMINAL: COMPARE WIDTH AND HEIGHT.

FIG. 6.—A NORMAL SKULL: COMPARE WIDTH AND HEIGHT.

The more highly developed the mental powers, the more connected will the various centres of the brain become by means of intricate channels of the freest intercommunication. Though the centres themselves are distinct, all of them are inter-united, and the activity of each depends on its relation to the others. It is, therefore, a mistake to look for a protuberance of brain-matter, or a bump, on its outer covering, the skull.

Other things being equal, the greatest amount of mental capacity and vigour is allied with the largest quantum of cerebral substance. All observation as regards men and animals proves that the energy of any nervous centre always bears a direct proportion to its bulk, whether absolute or relative. Every organ of our body increases in size in proportion as it is exercised within the limits of its physiological capacity, and this holds good for the brain as well. With increased mental work the brain will show an increased growth.

The entire brain may be too small. As a rule, however, when the brain is too small it is not dwarfed equally in all its parts, but is specially so in the prefrontal and frontal regions—in those parts which manifest the peculiarly human faculties and sentiments; while the hinder and lower parts of the brain—those which are the seats of the appetites and propensities—are far less affected. Hence, also, the peculiarly animal look.

Considering that the mental functions of the brain include not merely intellectual aptitudes and moral sentiments, but also the affections and instinctive tendencies to self-preservation, it is evident that the measure of the absolute volume of a man's brain cannot be taken as an index of his intellectual capacity alone. No matter whether the head be large or

small, and the brain heavy or light, the *entire* mass will give no clue to the intellectual ability or moral character of the individual. There have been men famous for their abilities and learning who have had exceptionally large heads, and some with exceptionally small ones. We must compare the relative development of different regions in the same brain to come to a conclusion. Investigation has revealed the fact that a high development of a particular region, as compared with the rest of the brain, is associated with special mental powers of which the region in question is the essential basis. Just as in animals that possess an extraordinary sense of smell there is a relatively enormous development of the olfactory bulbs, so in men whose chief characteristic is an extraordinary degree of purely intellectual power the pre-frontal lobes will be found remarkably developed as compared with the remainder of the cortex. The differences in the mental powers of members of the same family arise wholly from the various degrees of development in the different cerebral parts. All normal human brains exhibit the same parts and have the same primary mental powers, but vary in the relative development of the different convolutions, principal and accessory. This relation is infinitely varied, hence the great variety in the character of men and the different degrees of development of the primitive mental powers in the same individual.

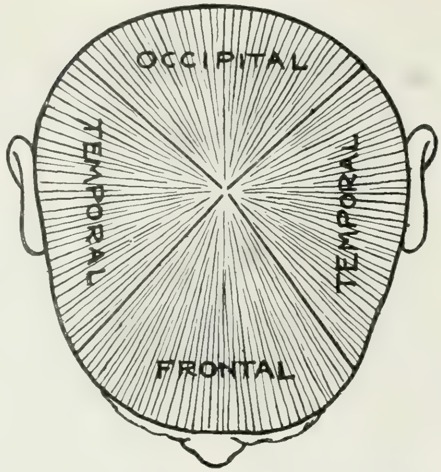


FIG. 7.—THE COURSE OF THE BRAIN FIBRES, PASSING FROM THE CENTRE TO THE CIRCUMFERENCE: LOOKING DOWNWARDS.

FIG. 8.—THE COURSE OF THE BRAIN FIBRES, PASSING FROM THE CENTRE TO THE CIRCUMFERENCE.

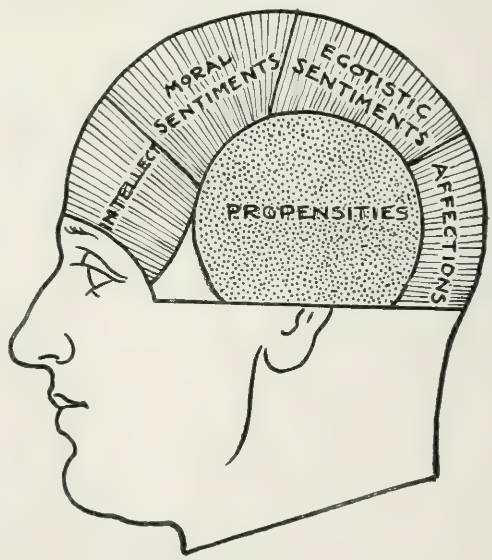


FIG. 9.—THE COURSE OF THE BRAIN FIBRES, PASSING FROM THE CENTRE TO THE CIRCUMFERENCE.

It will be seen, then, that we lay great stress on the relative proportion of the several parts of the brain as an indication

of mental manifestation. But not in every case where the size and shape of the brain proves favourable will the mental operations be well performed, for there are other things which may impart unusual energy of function or impede the activity of the brain. The digestion, circulation of the blood, or other functions may be out of order, and exert an exciting or deteriorative influence on the brain, however well-proportioned. Quality is another factor in estimating activity, but not the primary one. It only proves of avail when two or more individuals are compared with one another, and in such cases, inasmuch as the brain partakes of the general constitution, its quality can be judged of by the general structure of the body—texture of skin, hair, nails, etc., development of bones, muscles, and so forth. With only the brain of a healthy subject before us, the quality of each part is the same, hence that part which is the largest in quantity will have been the most active.

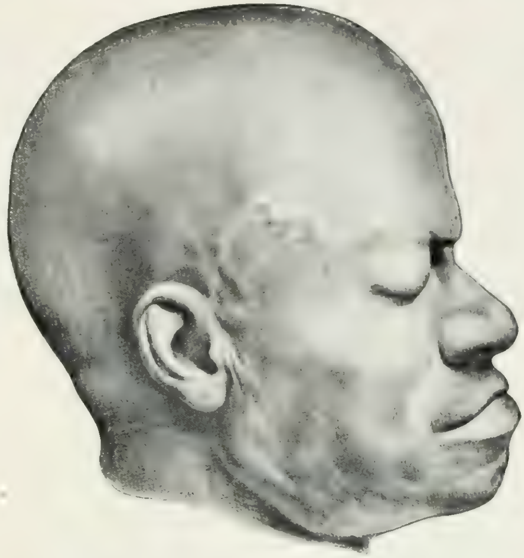
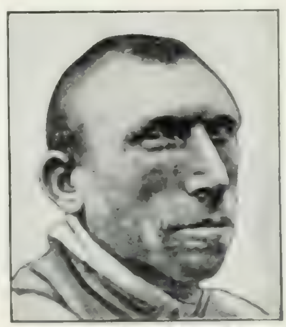


FIG. 10.—BLACK BUT BENEVOLENT.

This is the head of a negro who saved the lives of 400 people during an insurrection in St. Domingo. Notice the development of the superior frontal region, where the ethical and religious sentiments are situated.

The size and shape of the brain can be estimated with tolerable accuracy in living men, for the skull represents, for all practical purposes, a true measure of the dimensions of the brain in all normal individuals. The head of a new-born child is from 13 to 14 inches in circumference; those of adults are found to vary from 20 to 23 inches. The cranial cavity, and hence the whole contour of the head, enlarges in the same proportion as the brain increases in size, and this simultaneous enlargement continues so long as the head grows. This fact sufficiently shows that the cranium yields instantly to the brain, which augments in volume; and as the bones of the cranium until the age of puberty are very thin—about a line in thickness—it follows, of course, that the external outline of the cranium is precisely similar to the surface of the brain. One must bear in mind that the skull is a living substance, and that absorption, nutrition, decomposition, and new formation of bone particles are continually going on. Many would have us believe that the brain obeys the inert resistance of the cranium because the latter is the harder, inspite of evidence afforded to the contrary in the case of hydrocephalic subjects. They forget also that the continual action of nature in nutrition changes and modifies the hardest of substances as easily as the softest



From a Photograph.

FIG. 11.—NOT A GOOD HEAD.

A pig driver who committed rape and manslaughter. The head shows mental coarseness and criminal propensities. Compare with intellectual and moral types.

parts, through the successive deposition of nutritive elements and the re-absorption of those that have remained a long while in the system. Wrong conclusions have been drawn from the appearance of the brain when taken out of its bony box. Then, no longer being supported on all sides, it sinks down and flattens out, though it has filled the cranial cavity completely during lifetime. It may with confidence be said that every segment of the skull represents some particular part of the brain lying beneath it, and that groups of convolutions do modify the shape of the skull, and possess visible representations upon its outer surface. I have nothing to say, however, in defence of *bumps*. The difficulty with reference to the frontal sinus has also been much exaggerated. In children one may ignore it altogether; in women a slight allowance will have to be made; and in men the size of the other bones of the body will tell us what sized sinus to expect. The frontal sinus, even when very large, affects only the lowest part of the pre-frontal lobes in their *median* line, but does not affect the width of that part of the forehead or its length from the ear forward. Those who look for *bumps* will be puzzled by a frontal sinus, but not those who use our method of estimating the relative size of the various brain regions.

FIG. 12.—NORMAL SKULL: SIDE VIEW.
Compare with Fig. 13.

The brain of most men ceases to grow after thirty—at least perceptibly—but sometimes not till forty. That depends entirely on the degree of mental activity and amount of fresh knowledge acquired. In old age and in the insane the skull undergoes certain changes, but these need not be considered here.

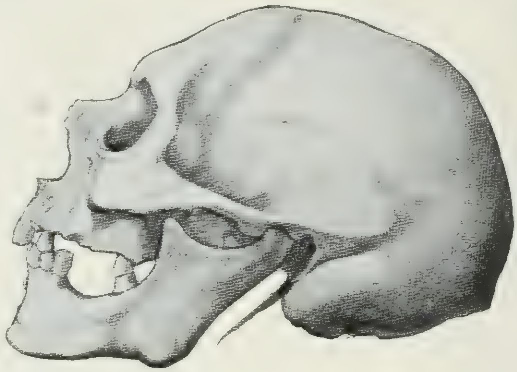


FIG. 13.—SKULL OF AN IDIOT.
Notice the shape of the frontal bones.

The frontal lobes in man reach the greatest development in volume as compared with all other animals. As we ascend the scale of animal intelligence, so we find that in proportion to the rest of the brain the frontal lobes increase in size, until their surface measures one-third of the entire surface of the brain. The frontal lobes, even of the highest apes, reach in size only those of the lowest microcephalous idiot; and since the other lobes of the brain in man and animals show no such disproportion, we may draw the inference that the frontal lobes contain those centres which are distinctly human—that is, the centres for the purely intellectual operations and moral sentiments. The greater mass of the frontal lobes—*i.e.* with the exception of the central convolutions which we reckon as belonging to the parietal lobes, lie in front of a line drawn from the opening of the ear to the same point on the other side across the top of the head. Speaking more correctly, it is that mass of

brain which lies between a plane held vertically upwards between the openings of the ears and another held nearly horizontally from the ridges of the eyebrows to meet the first plane. If the mass of brain between these two planes and the convex surface predominates greatly over the remainder—if it be relatively very large—one may draw the inference that the manifestation of the superior mental powers, intellectual and moral, in such a man will be greater than the manifestation of the affections and propensities, and that his animal tendencies will be held in abeyance. On the contrary, if this brain area be small as compared with the mass of the remaining lobes, then the animal characteristics preponderate over reason and moral sense. It is not a question of protuberance or depression of the surface of the brain or skull, but it is a question of a correct estimation and comparison of the relative development of brain masses. Wherever you go and wherever you are, in street or home, public or private assembly, you will be able to verify the above. Men of intellectual and moral eminence, all the world over, of whatever nation or creed, have large frontal lobes. You need not be a philosopher or a vivisector, you need not be an anatomist or a physiologist, you need only use your eyes to confirm this statement. The more vaulted the frontal bone, the more room for the frontal brain; but do not forget that this represents only one surface. A receding forehead is, therefore, quite compatible with marked intellectual power, if the breadth, height, and depth of the frontal lobes are good. It matters not whether the entire head be large or small, as long as the frontal area has large dimensions as compared with the rest.

FIG. 14.—SIR JOHN F. W. HERSCHELL.
Notice the length, height, and breadth of the frontal lobe.

The larger the anterior lobes in proportion to the rest of the brain, the more refined will be the expression of the emotions and even of the passions of man, and the greater control will he be able to exert over them. Let the frontal lobes be arrested in development or destroyed by disease, then the struggle between the lower instincts and the ethical feelings may cease, and instead of a rational man we see a creature given over entirely to the satisfaction of his lower desires. Anything that irritates the frontal lobes—as, for instance, inflammation, or the growth of a tumour—causes an increased activity of the mental processes of perception, association, and reproduction—in other words, a rapid flow of ideas. The other lobes of the brain being unaffected and deprived of the control of the intellect, manifestations of the natural feelings and animal spirits occur.

Vivisectors found after destruction of the frontal lobes in dogs and monkeys that the curiosity to observe, which is so marked in monkeys, is lost; that they are not able to receive new impressions, or to remember or reflect on the old; and that, since they can no longer criticise,

they become timid and easily excited. All the emotions and propensities remain intact, only increased in activity for want of control; but they no longer show gratefulness, cannot adapt themselves to new surroundings, neither learn anything new nor regain what they have forgotten. Experiments on animals thus confirm our view that the frontal lobes are the centres of perception and reflection, and the centres for the moral sentiments so far as their rudimentary existence can be demonstrated in the lower creatures, and that they are, in addition, centres of inhibition against the instinctive impulses.

The frontal lobes may be divided into two segments:—

1. The anterior segment, termed the pre-frontal lobes, which lies on the orbital plate and against the forehead up to the anterior border line of the hair in men who are not bald.

FIG. 15.—OLIVER CROMWELL'S PORTER: A RELIGIOUS FANATIC.

A large top region out of proportion to the rest of the brain. The type of the mystic, for whom worldly pleasures have no fascination. The purely intellectual region is small.

2. The superior segment extending from this line to the vertical plane before described, the part which normally is covered by hair.

The first part may be further divided into a lower portion, related to the perceptive range of the intellect; and an upper portion related to the reflective range, or reason proper. The latter portion, measured, of course, from the ear, will be found prominent in men whose knowledge rests chiefly on reason, is theoretical, as opposed to practical knowledge, the knowledge of facts of the man of observation, in whom the former will exceed in size.

The second or superior segment is the region of the ethical and æsthetical sentiments (anteriorly) and the religious sentiments (posteriorly)—a region which is non-existent or rudimentary in animals, and very small in typical criminals and in all those lower races of mankind which are known for their barbarous and inhuman dispositions.

Now we come to consider the temporal lobes. Men, like animals, possess a certain part of the brain which administers to selfish tendencies or propensities, planted herein because they are necessary for the preservation of the individual. What is the good of an animal's brain unless it is necessary for the manifestation of its instincts? The large size precludes that the amount of the nervous matter represents the measure of the intellect. But if we admit that animals have instincts which are in relation to certain brain-parts, we must also admit similar unconscious impulses in the human being. Vivisectors have found that after destruction of the frontal lobes the animals so deprived had lost the inhibiting power over their propensities, so that their character changed for the worse. On the other hand, after destruction of those areas which represent the temporal lobes in ferocious animals, the latter became quite good-natured.

A large development of the temporal lobes, as shown by great width between and depth of the ears, indicates great strength of the animal passions and of the physiological force of the constitution. If this breadth is balanced by a proportionate development of the intellectual and moral region the character is strong, yet attractive. We must never estimate the strength of the animal dispositions by the size of the mass of the temporal lobes alone, but should compare this with the development of the rest of the brain, particularly the size of the entire frontal lobes, the intellectual and moral regions, which inhibit, or at least modify, the manifestation of the instincts originally intended for self-preservation. If a man lived altogether alone on an island, every impulse of the self-preserving instinct would be right. But when living in society, the advantages of social life can be reaped only when these impulses are held in check by the moral instinct, that sympathetic control whereby a man is prompted to postpone the seeking of his own good for the good of others. For a long time strength, courage, or adventitious tricks decided which was the emergent type, until we reached the stage at which the intellect became in the ascendant. Then it became no longer necessary to rob others for our own preservation, but means were found to enrich ourselves by approved methods; it was no longer necessary to kill our enemies and those who opposed our progress, from the fact that we could overcome them by less painful means. Were there only propensities and intellect, many men would use their intellect for the gratification of their propensities, as animals do; but the evolution of the moral sense in human beings countervailed such tendency. If man is better able to govern his instincts or passions than animals, it does not at all follow that those passions or instincts are more feeble: they are simply more under the control of the understanding.

FIG. 16. A BURGLAR.
Notice the relative size of the temporal region and compare with intellectual and moral types.

At the apex of the lower segment of the temporal lobe there is a centre for hunger and thirst, which is connected by a branch of the vagus nerve with the stomach. This centre was first discovered by a physician-phrenologist, later independently by experiment on animals, and recently confirmed by clinical observation. The feeling of hunger incites the animal to obtain food. In order to maintain its existence it must destroy or kill for food—it must have the desire and strength to overcome its prey. This is the function of the greater portion of this segment. This instinct being highly essential to

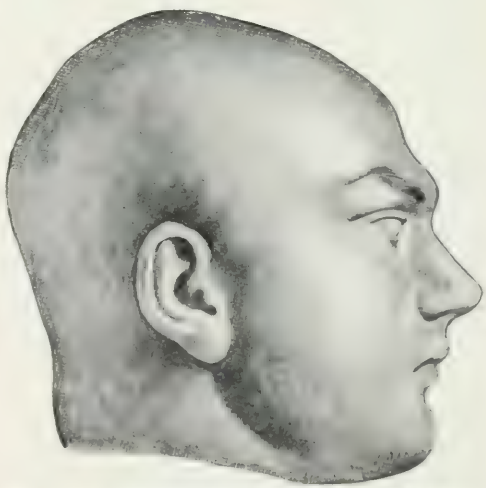


FIG. 17.—A CRIMINAL WHO MURDERED HIS FATHER.
Compare the development of the [illegible] *with Fig.* [illegible]

carnivorous animals, this part of their brains is highly developed, and in ferocious animals it causes an increased bulging of this region of the skull. This is also the case in all men disposed to violence. The instinct of self-preservation includes another tendency which appears to be connected with the more posterior portion of this segment. The animal, to maintain its existence, must be alive to, and able to remove, the dangers by which it is surrounded, and able to inflict injury on its foes. This imparts a combative instinct. That the sight of its foe should rouse an animal's energies to furious rage, whereby important vascular changes are developed all over the entire body and the strength of every muscle is exalted, is a reflex mechanism of immense preservative value in the struggle for existence. Vivisectors have confirmed our observation, for excitation of this part in animals produces symptoms of rage, such as spitting, lashing of the tail, opening the mouth wide, and making a bound forward, wrathful vocalisation, and retraction of the ear, which occurs in all animals before they begin to fight. The instinct of self-preservation in man is not limited to the fighting tendency and the exercise of physical resistance, but gives executiveness, efficiency, and force to all the other mental powers.

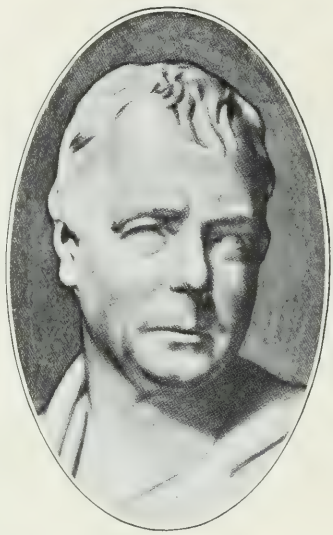


FIG. 18.—SIR WALTER SCOTT.
Note the size and development of the frontal lobes in the head of the great novelist.

Irascibility or anger is the active form of the instinct of self-preservation. Anger is an emotion which gives neither pleasure nor pain. It gives an impulse to inflict injury on the cause of the emotion. Discomforts of life make us angry, and the protest is particularly strong in children. A hungry man and a man suffering from disorders of digestion are irritable and easily angered; and, on the other hand, anger may promote indigestion. This relationship may be explained by the vicinity of the alimentive and irascible centres, and it may further account for the fighting tendency in drunkards. There are men whose intellect is not able to set limits to their impulsive feelings. Inward excitement runs unbridled into outward manifestation. Irritable to the highest degree, touched by the slightest impressions, they frequently react in the most passionate way on the most insignificant grounds. The emotion may lead to a total supersession of the intellectual capacity, and end by driving them in their utter irresponsibility into acts of violence and crime. The author has noted over 350 cases of violent mania in which this part alone was found diseased.

In the upper part of the temporal lobe, anteriorly, just over the centre of hunger and thirst, or nutritive instinct, is a centre which seems related to the hoarding tendency. It originated when animals found it useful not to have at all times to hunt for food, which may be scarce at certain periods, and began to store up things for use. Thus was developed a tendency to make provision for the future. Man not only stores up provisions for the winter, but he acquires property of all kinds for all his life and for his posterity. The brain area in question only gives the tendency or habit, but not the ability, unless combined with intellect and other requisite qualities. It imparts the love of possession. Of course, property may

be acquired honestly or dishonestly—that depends on the organisation of the rest of the brain.

The posterior part of the superior

FIG. 19.—SKULL OF A CARIB.

segment of the temporal lobe is also connected with the instinct of self-preservation. Animals had to protect themselves against their numerous enemies to prevent being themselves destroyed; hence arose a tendency to concealment, which was also found useful in approaching their own prey, and a feeling of suspicion. Suspicion is a protective instinct, and hence a necessary mental quality. It is a propensity to conceal intentions by acting indirectly and cunningly. When moral education is deficient, it leads to falsehood and deception. On the other hand, a person with this brain-part relatively small is disposed to be open, direct, and frank in his manners and conduct. I have found mania of suspicion and persecution to be connected with disease of this area.

The parietal lobes may also be divided into two portions—upper and lower. The former has been shown to be connected with the egotistic sentiments; the latter is anatomically connected with the posterior part of the temporal convolutions, and so is its function. The struggle of different species of animals for existence would expose, especially the weak, to continual danger. The knowledge of past dangers would make them cautious, and also cause them to fear their enemy. Hence they use their intellectual powers in conjunction with the emotion of fear, and keep a look-out. Thus do they develop foresight. This brain-area is most developed in those animals and those men that are timid, apprehensive, and disposed to take every precaution to prevent future trouble and danger. This must happen automatically, or else it is useless. There is often no time for reflection. Without the emotion of fear

FIG. 20. SKULL OF RAFFAELE, THE GREAT PAINTER (1483–1520).

animals would not have apprehended danger. That the voice of a dangerous oppressor should depress an animal's energies to fear, diminishing the vascular

tone and producing a deathlike appearance, must have been originally of huge preservative value in the struggle for existence. An animal having suffered frequent frights develops fear. Fear is the chronic form of fright. From it developed a propensity to watch for coming difficulty and trouble, to avoid danger, and to restrain present gratification when it may prove thereafter injurious. In excess, it produces hesitancy and irresolution, when a bold, decided course is required; when it is deficient, carelessness and recklessness are often manifested. The skulls of herbivorous animals are wide across the parietal bones; those of carnivorous animals are wide across the temporal bones. Injury or disease of the lower parietal area I have found to lead to excessive manifestation of fear and melancholia. Vivisectors have shown that electrical excitation of this brain-part in animals produces an expression of fright; and its destruction causes loss of fear and imperception of danger.

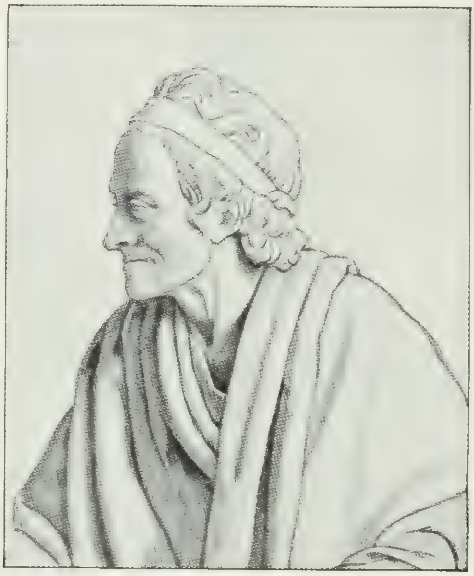


FIG. 21.—VOLTAIRE.
Notice the development of the frontal lobes in the great French philosopher and cynic (1694–1778).

The posterior or occipital lobes will be found to correspond in development with the degree of affection and attachment a man or woman possesses. They seem to contain the centres which form the constituent elements of the human affections —the enduring love of parent to offspring, necessary for the maintenance of the species, especially when these are as limited as they are in the human species. Numerous anthropologists have recorded their observation that the occipital lobes are more highly developed in women than in men, and, indeed, one rarely sees a straight back to the head—so common in men—amongst women. It is not a question of coiffure, for one of the distinctions of male and female skulls is this occipital development. Moreover, it has been ascertained by careful measurements that women have more length of brain posterior to the central fissure than men, who, again, have more brain anterior to it. In other words, the average man has more intellect than the average woman, and the latter, again, has more feeling than the average man. In women not only is the attachment to offspring but also the attachment to friends much stronger than in men. Whoever has gained the friendship of a woman is sure of the success of the affair in which she serves him. Men are much more easily discouraged in similar circumstances. Those persons who have relatively small occipital lobes are lacking in tender emotion, wanting in affection, and are apt to be stiff and formal. A man thus organised may have a high sense of duty and sound moral instinct, and provide all accessories, and even comforts, for his wife and children, yet as a husband and father he will prove a failure.

The principles of phrenology only require to be made known for it to be rescued from its present position — a Cinderella amongst the sciences:

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POISONOUS, IF PRETTY: SOME PLANTS TO BE AVOIDED.

1. RED BRYONY (*BRYONIA DIOICA*). 2. WOODY NIGHTSHADE (*SOLANUM DULCAMARA*). 3. FOXGLOVE (*DIGITALIS PURPUREA*). 4. HEMLOCK (*CONIUM MACULATUM*). 5. DEADLY NIGHTSHADE (*ATROPA BELLADONNA*). ALL ARE VIRULENTLY POISONOUS

SOME COMMON POISONOUS PLANTS.

By J. FRASER, F.L.S.

A LARGE number of the more virulently poisonous plants in this country have been introduced and cultivated as ornaments of the garden, and some of them have become naturalised. In former times every herb or vegetable was supposed to possess a particular virtue and to constitute a "simple" remedy for some particular ailment, disease, or malady. Hence we have the terms "simple," meaning a medicinal herb, and "simpler" or "simplist," a person who collected and dealt in simples or medicinal herbs. A very large proportion of the popular names of plants in use at the present day are very old, and bespeak a familiarity with them on the part of our ancestors which to-day we do not possess. In a large measure this is due to our reliance upon the physician to supply us with the necessary medicine. The subject is a vast one, and for that reason this short paper will be devoted chiefly to a consideration of British poisonous plants.

Many members of the buttercup or crowfoot order are of a bitter and acrid nature, some of them intensely so. The buttercups (*Ranunculus bulbosus*, *R. repens*, and *R. acris*) which cover the rich, moist meadows with dazzling sheets of yellow in May, and keep on flowering more or less intermittently till autumn, are of an acrid nature in the fresh state, and their juices have the property of blistering the skin. Before the introduction of cantharides, or Spanish flies, they were used as vesicatories. This property resides in all parts of the plant, but in *R. bulbosus* it is more particularly concentrated in the root. This species in olden times was much in request, as it was reputed to raise blisters with less pain than Spanish flies. The roots of *R. bulbosus* have been applied to the joints in cases of gout. The action of all the crowfoots, however, has been described as

FIG. I.—THE "WICKED" RANUNCULUS (*RANUNCULUS SCELERATUS*).

This was at one time used by beggars to raise blisters on their arms and hands and thus excite the pity and alms of the compassionate.

uncertain, while they have been blamed for leaving raw and painful ulcers.

In olden times even beggars were acquainted with the properties of *R. bulbosus*, *R. sceleratus* (Fig. 1), and possibly other species, for they used the plants to raise blisters on their arms in order to excite compassion when begging. Some botanists have described these crowfoots as blistering the palm of the hand carrying them; but this experience is confined to those having peculiarly sensitive skins. Cattle are said to have their mouths blistered by eating buttercups

when freshly turned into a field of young grass. Under ordinary circumstances, however, the plants are left untouched by cows; and it may be remarked that buttercups have nothing to do with the

FIG. 2.—THE ACONITE OR MONKSHOOD (*ACONITUM NAPELLUS*).

1, Leaves and flowers; 2, conical root of monkshood; 3, root of horseradish, shown for comparison. Deaths are not infrequently caused by people mistaking the dark-coloured, conical roots of the monkshood for the light-coloured, thong-like roots of the horseradish.

rich yellow colour of butter. Curiously enough, the bitter properties of the crowfoots are confined chiefly to the land species, including *R. Flammula*, *R. arvensis*, and *R. hirsutus*, in addition to those already mentioned. *R. sceleratus* is particularly acrimonious, and the term "wicked" is a more literal translation of the name than "celery-leaved" often (but erroneously) applied to it. The acrid nature of the crowfoots is wholly destroyed or removed by distillation. When made into hay, the land species lose their acrid properties. The aquatic forms have been used as cattle food both in this country and on the Continent.

The hellebores have long been known as virulently poisonous, yet the Christmas rose (*Helleborus niger*) and the bear's-foot (*H. fœtidus*) have enjoyed great reputation in popular medicine as vermifuges and purgatives, both having been accorded a place in "The London Materia Medica." The bear's-foot and the green hellebore (*H. viridis*) are British. Other British plants belonging to the crowfoot order, and found to be more or less poisonous, are the anemones, marsh marigold (*Caltha*), larkspur (*Delphinium Ajacis*), and the common columbine (*Aquilegia vulgaris*). The larkspur at one time enjoyed the reputation of possessing healing properties, and the whole plant of the columbine has been used in medicine; but Linnæus states that children have lost their lives by eating it. The berries of *Actæa spicata*, or bane-berry, are poisonous, while the tuberous or fleshy roots of the allied American species of *Cimicifuga* have been used by native practitioners as an antidote to snake-bite.

The king of terrors, however, amongst the whole of this group, as far as British plants are concerned, is the monkshood or aconite (*Aconitum Napellus*) (Fig. 2). All parts of the plant are poisonous, the roots most virulently so, and deaths have been caused by it. The ancients regarded the aconite as the most virulent of all vegetable poisons known to them. In more recent times Dodonæus relates that five persons at Antwerp in his day ate of the roots and died; and Matthiolus states that a criminal was put to death by being made to eat a dram of the root. Deaths have also occurred through eating the roots in mistake for horseradish. The short, dark-coloured, conical roots, however, in no way resemble those of the horseradish, which are long, thong-like, and yellow-white in colour. The virulent nature of the aconite is due to the presence of a powerful alkaloid, *aconitine*. Nevertheless, the roots of this and allied species in Europe are used

medicinally for allaying pain in rheumatic complaints.

There are three classes of vegetable poisons—(1) the *irritants*, the effect of which on the human system is to cause violent pain and cramp in the stomach, nausea, vomiting, convulsions, and, in extreme cases, death; (2) *narcotics*, which cause drowsiness, stupor, stiffness of the limbs, cold perspiration, and delirium; (3) *narcotic irritants*. The antidote to any or all of these herbs in the case of accident is to use a powerful emetic, so as to empty the stomach as quickly as possible of the whole of its contents. Common salt, camomile, and mustard flour are emetics; and some of them should be used at once; but in any case the aid of the physician should be procured without delay.

The poppy order, exclusive of the fumitories and their allies, is notable for the milky juice permeating the whole plant, and possessing in different members properties equivalent to all the three classes of vegetable poisons. The blood-root of Canada (*Sanguinaria canadensis*) and the celandine are acrid, emetic, and purgative, representing the "irritants." The opium poppy (*Papaver somniferum*) (Fig. 3) represents the "narcotics," and the plant, though not native, has become naturalised as a cornfield weed in chalky districts. The red or corn poppy is only used in medicine as a colouring agent. The seed-vessels of the opium poppy are used in fomentations for allaying pain. The third type of poison—namely, the narcotic acrid—is present in the seeds of *Argemone mexicana*, but this poppy is not British.

The opium poppy is the most important plant of the whole order. The milky juice is narcotic, and an extract from it has been used as a sedative; but the species has been cultivated from early antiquity for the sake of the opium prepared from the juice. The principal supply comes from Asia Minor, Egypt, Persia, and India. Besides being naturalised in England, it has been cultivated in gardens for a long period for the beauty of its flowers. All parts of the plant are permeated with this milky, narcotic juice, but it abounds most in the nearly full-grown but green capsules, and for these seed-vessels alone the plant is grown for medicinal purposes. The London market was at one time supplied from the cultures at Mitcham in Surrey, and the method of preparation was much the same as that employed in the time of Dioscorides. As a medicine, opium is an anodyne and a soporific—that is, it allays pain and causes sleep. In moderate doses it stimulates the pulse and increases the heat of all parts of the body, quickens respiration, invigorates the bodily and mental faculties, and exhilarates even to intoxication; but in time these effects are succeeded by languor, sleep, thirst, tremors, and other symptoms of debility. In

FIG. 3.—THE OPIUM POPPY (*PAPAVER SOMNIFERUM*).

large doses the stimulating effects are scarcely apparent, but the pulse becomes enfeebled, this being followed by drowsiness, delirium, cold sweats, convulsions, and, in extreme cases, apoplexy and death. On dissection, the stomach and intestines

have all the appearance of having been violently inflamed. When an overdose of opium has been taken, recourse should be had to a powerful emetic, such as sulphate of copper or sulphate of zinc dissolved in water. The vomiting should be encouraged for some considerable time. Good draughts of vinegar and water should also be taken at intervals afterwards. The victim should be kept awake, even by means of rough usage, until the effects of the opium have been worked off. In medicine the extract known as morphine, or morphia, is largely used by practitioners for inducing sleep and allaying pain, and is applied in various ways. It is the sedative principle of opium, and, after extraction, is acted upon by chemicals till crystallised, and then purified by

FIG. 4.—THE GREATER CELANDINE (*CHELIDONIUM MAJUS*).

The yellow, acrid juice of this herb is still used by gipsies for getting rid of warts.

recrystallisation, the crystals being colourless and lustrous. Laudanum, a well-known drug, is tincture of opium.

The character of a narcotic poison will have been gleaned from the effects of opium upon the human system, the symptoms being stupor, drowsiness, stiff-

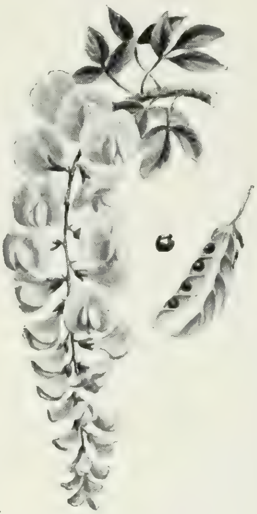

FIG. 5.—BEAUTIFUL BUT BANEFUL: THE LABURNUM (*LABURNUM VULGARE*).

Many children have been killed by eating the seeds of the popular "Golden Chain."

ness of the limbs, cold perspiration, vertigo, and delirium.

At one time the greater celandine (*Chelidonium majus*) (Fig, 4), enjoyed considerable reputation in medicine, both in this country and abroad, for the cure of various diseases and ailments; but its use seems to have completely fallen away in England, though the plant remains in the vicinity of villages and human habitations. Its dangerous properties should, however, be kept in view.

The fruits of the spindle-tree (*Euonymus europæus*) are considered to be purgative and emetic in an eminent degree, but, except in the matter of colour, they offer little temptation to the inexperienced to eat them. More attractive are the black berries of the nearly related *Rhamnus catharticus* and *R. Frangula*, which are strong cathartics. The bark of the trunk and branches is also purgative. Both species were at one time used in medicine. The tuberous

rootstock of the red bryony (*Bryonia dioica*) is strongly purgative and acrid. (*See* Coloured Plate.)

The handsome Laburnum (Fig. 5) is a dangerous subject. Several instances are on record of children having died through eating the flowers, pods, or seeds. The whole tree, in fact, is very bitter and emetic, although the young and green seeds are especially violent in their action. The principle is *cytisine*.

The family of Umbellifers, of which the carrot, parsnip, and celery are well-known types, is well represented in this country, and notable for a variety of products, economic, medicinal, and poisonous. One of the properties of the order consists of aromatic oils; another may be classed as gum resins, chiefly

FIG 6.—THE FOOL'S PARSLEY *(ÆTHUSA CYNAPIUM)*.

When young this is sometimes mistaken for parsley.

used in medicine, and valued for their antispasmodic, expectorant, and stimulating properties. Some are used in cases of dysentery, diarrhœa, and hysteria. We are here most concerned with their poisonous properties, due to the presence of acro-narcotic poisonous substances dissolved in the watery juices of the plants.

FIG. 7.—THE HEMLOCK DROPWORT *(ŒNANTHE CROCATA)*.

Chiefly dangerous to cattle; but the roots have been mistaken by boys for radishes.

The Umbellifers belong, therefore, to the third class of vegetable poisons, and would seem to consist of a combination of the first two classes, judging from their effects on the human frame. *Anthriscus sylvestris*, *A. vulgaris*, and *Æthusa Cynapium* fool's parsley) (Fig. 6) are poisonous, and accidents are liable to happen owing to the resemblance of the foliage (especially of young plants) to that of parsley. The hemlock dropwort (*Œnanthe crocata*) (Fig. 7), *Œ. phellandrium*, and other species are more or less poisonous—sufficiently so, under certain conditions, to be fatal to human beings, and also to cattle. As recently as the spring of 1902 some boys on the banks of the Thames at Putney dug up some fleshy roots of *Œnanthe crocata*, and one of them ate freely of the same, thinking them to be radishes. He was

suddenly taken ill, and died before medical aid could be summoned. Hemlock poisoning was the verdict, but further evidence proved that the roots were those of the water dropwort. No doubt the symptoms of poisoning by this plant are closely identical with those of the hemlock (Coloured Plate). The latter, though a deadly poison, is used in medicine as an anodyne, and acts in much the same way as opium. Water hemlock, or cowbane (*Cicuta virosa*), is poisonous to man and cattle, but, happily, it is far from common. Antidotes to poisoning by hemlock are strong tea and coffee, stimulants, and tannic acid. Castor oil, emetics, and stimulants are also recommended for poisoning by water hemlock. A speedy emetic must be employed in the case of poisoning by the roots of the water dropwort, these being the most deadly part of the plant.

FIG. 8.—THE CAPER SPURGE (*EUPHORBIA LATHYRIS*).

The fruits have been pickled and sold for capers, which they somewhat resemble, but they are acrid and poisonous.

Ivy and privet berries are strongly purgative and dangerous to children, who should be warned against them. Several plants with a milky juice are more or less dangerous, although many of their allies are innocuous. The drug *lactuarium*, obtained from *Lactuca virosa*, is used in medicine as a substitute for opium, as it is said to act as a sedative, and is less injurious in its effects upon the system. This property is due to *lactucine*. The milky juice of campanulas and lobelias, amongst common garden flowers, is very acrid, but the latter are the more deadly. The two British species are local and far from common. The milky juice contains *atropine*, which produces burning effects, similar to those of belladonna. The symptoms are burning sensations and vomiting, followed by death. The powdered leaves and seeds are the parts employed. In severe cases speedy emetics and the stomach pump should be used; purgatives and tannin will answer in milder cases.

The milky juice of the spurges, or *Euphorbias*, is very acrid and poisonous. There are ten British species, and four exotics have become naturalised in places. *E. Helioscopia* is used in rural districts for destroying warts. The fruits of *E. Lathyris* (Fig. 8) are sometimes pickled as a substitute for capers; and although the poison they contain is largely neutralised by salt and vinegar, their extensive use cannot be otherwise than deleterious. The seeds contain "oil of euphorbia," which is purgative to a dangerous degree. The juice of all the *Euphorbias* has a blistering and irritating effect upon the skin. Boys have died through eating *E. Helioscopia* and *E. Peplus*, two very common weeds.

The annual and perennial mercury (Fig. 9) and the box of our gardens have no milky juice, but they belong to the same family as the *Euphorbias*. All are poisonous, the seeds of mercury being a violent and irritating purgative. The leaves and bark of the box have proved

drastic purgatives to the lower animals, and have been in some cases fatal.

The *Solanum* or potato family includes many deadly poisonous plants, and as the fruit of the poisonous ones is a berry, often highly tempting, the danger to children, and even to adults, who may be ignorant of their nature, is considerable. The poisonous principle in solanum is *solanine*, and this has been detected in all the species analysed. The woody nightshade, or bittersweet, and the black solanum (Fig. 11) are British, the former having red and the latter black berries. The poisoning of children is recorded against both of them. Imperfectly ripened or green berries are more highly poisonous than those that are perfectly mature, so that immunity from poisoning in some cases may be attributed to the selection of perfectly mature berries. Solanine is an acro-narcotic poison, and the berries of the black solanum have produced colic,

FIG. 9.—THE PERENNIAL DOG'S MERCURY (*MERCURIALIS PERENNIS*).

To this plant some of the mysterious deaths of cattle which occur every year are due.

vertigo, and convulsions in children. The potato is also a solanum, and contains the same principle as the rest, but only to a small extent in the tubers, and that chiefly in the skin. Green tubers are to be avoided, however, as food. The

FIG. 10.—A PRETTY COUSIN OF THE POTATO: THE THORN-APPLE (*DATURA STRAMONIUM*).

This curious plant is a vagrant, and rarely makes its appearance in the same spot for two consecutive years.

remedy recommended for poisoning by the solanums is castor oil.

The black and shiny berries of belladonna, or deadly nightshade (*Atropa Belladonna*) (Coloured Plate), are tempting to children by reason of their appearance and sweet taste; and, though the poison is least concentrated in ripe fruit, many cases of poisoning have occurred. The principle is most concentrated in the root. The berries act in a varying degree upon different people, according to age. This poison dilates the pupil of the eye, causes the victim to be highly excited for a time, and to have difficulty in walking, this being followed by stupefaction and death. The young roots possess *hyoscyamine* only, while other parts of the plant contain that and *atropine*, though the berries of the wild plant contain the latter only.

The North American mad-apple, or

thorn-apple (*Datura Stramonium*) (Fig. 10), has become naturalised in places in this country. It may be recognised by the spines upon its fruits, which resemble a horse-chestnut. The whole plant is poisonous, but *daturine* is most concentrated in the seeds, which have been eaten in the green state, when they are sweetish. The remedies suggested for belladonna, thorn-apple, and henbane (Fig. 12) are coffee, stimulants, emetics, and purgatives. The sufferer must be kept awake in the same rough-and-ready manner as the victim of opium.

The foxglove (*Digitalis purpurea*) (Coloured Plate) is a familiar plant in Britain. All parts of the plant are dangerously poisonous, the seeds being most virulent in this respect. Wild plants contain more *digitaline*, the deleterious principle,

FIG. 11.—THE BLACK NIGHTSHADE (*SOLANUM NIGRUM*).
A common weed of cultivation.

than cultivated ones. It is useful as a sedative in the case of heart disease, but many accidents have resulted from its improper use by unqualified persons. The British species, as well as *D. ochroleuca*, *D. lævigata*, and *D. ferruginea*, produce vertigo, severe vomiting, and, in extreme cases, death. The remedies re-

FIG. 12.—THE HENBANE (*HYOSCYAMUS NIGER*).
This is generally found in rubbish heaps and on pieces of waste ground.

commended are emetics, such as mustard and water, followed by strong tea, stimulants, or half a dram of tannic acid in water.

The daphnes are to be avoided as dangerously poisonous. The two British species (*D. Mezereum* and *D. Laureola*) are not very common in a wild state, but frequent in gardens. All parts of the plant, including the bark and berries, contain an acrid, irritant, and narcotic principle, which acts in a similar manner to aconite and belladonna. The juice of the bark blisters the skin, and the berries have been the cause of many accidents, especially to the young and unwary. This poison usually acts as an emetic, and should be encouraged by the use of gruel. If the poison has passed through the stomach into the intestines, it must be ejected by means of good

doses of castor oil. The daphnes are highly ornamental, but where the berries would put danger in the way of children the young fruits should be removed as soon as the flowers drop.

It has long been known that the yew (*Taxus baccata*) is baneful to horses and cattle, which may happen to eat the leaves. The scarlet, cup-like *aril* surrounding the seeds is perfectly harmless when quite mature, and children frequently eat it without the slightest inconvenience. The seeds are admittedly poisonous, however, although thrushes eat them largely with impunity, probably because they pass rapidly and uncrushed through the digestive canal. Emetics are the first remedy to be adopted in the case of poisoning, to be followed by castor oil and stimulants.

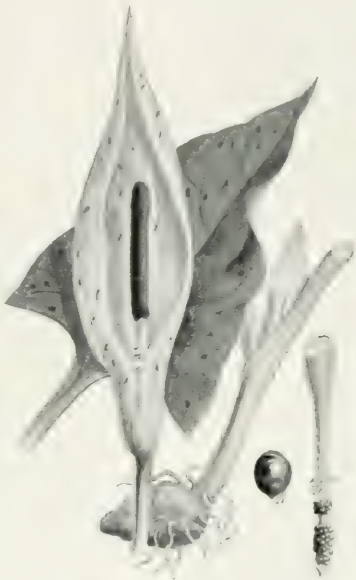

FIG. 13.—LORDS AND LADIES, CUCKOO PINT *(ARUM MACULATUM)*.

All parts of the plant are poisonous, but the bright scarlet berries, which make their appearance towards the end of the summer, are the most virulent of all.

The daffodil or Lent lily (*Narcissus Pseudo-narcissus*) is plentiful in a wild state in some parts of England, and the cultivated or garden forms are everywhere abundant. All parts of the plant —but especially the bulbs—are emetic, purgative, and irritant. Even the smell of the flowers acts injuriously upon some constitutions.

The scarlet berries of the black bryony (*Tamus communis*) are highly poisonous, and from the symptoms they produce may be classed among the narcotic acrid poisons. The plant is a rampant climber, common in many parts of the country, and the berries are highly attractive to children. The common *Arum maculatum* of woods, hedge banks, and waysides (Fig. 13) is poisonous in all its parts, but the tubers are more particularly irritant, though this property may be dissipated by means of heat. The starchy roots of the allied but less common *A. italicum* have been used as food, after being baked, under the name of Portland sago. Cases of poisoning by the berries are not uncommon. The symptoms are burning sensations, cramp, and convulsions, followed by death. Unless spontaneous vomiting occurs, emetics should be administered. Castor oil should be given if the poison has passed into the intestines.

(See also the List of Poisonous Plants on page 492.)

TABLE OF POISONOUS PLANTS.

Botanical Name.	Popular Name.	Locality or Habitat.
Aconitum Napellus	Monkshood	River banks, meadows, hedges.
Actæa spicata	Bane-berry	Copses on limestone.
Æthusa Cynapium	Fool's Parsley	Waste places, neglected gardens.
Anthriscus sylvestris	Beaked Parsley, Wild Cicely	Thickets, hedges, shady places, etc.
Anthriscus vulgaris	Common Beaked Parsley	Gravelly river banks, hedges and waysides.
Aquilegia vulgaris	Columbine	Woods, thickets, and bushy places.
Arum italicum	Italian Cuckoo-pint	Thickets and hedges.
Arum maculatum	Cuckoo-pint, Lords and Ladies	Woods, thickets, and hedges.
Atropa Belladonna	Deadly Nightshade, Dwale	Copses and waste places on chalk.
Bryonia dioica	Red Bryony	Hedges, thickets and bushy places.
Buxus sempervirens	Box	Woods and thickets on chalk; gardens.
Caltha palustris	Marsh Marigold	Banks of rivers, streams, and wet meadows.
Chelidonium majus	Greater Celandine	Hedgebanks near villages and houses.
Cicuta virosa	Water Hemlock, Cowbane	Wet places, ditches, etc.
Conium maculatum	Hemlock	Roadsides, banks of rivers and streams.
Daphne Laureola	Spurge Laurel.	Copses and hedges on chalk and clay.
Daphne Mezereum	Mezereon	Copses and woods.
Datura Stramonium	Thorn-apple, Mad-apple	Waste places and gardens; introduced.
Delphinium Ajacis	Larkspur	Cornfields chiefly.
Digitalis purpurea	Foxglove	Copses, banks, heaths, open woods.
Euonymus europæus	Spindle-tree	Woods, thickets, bushy places, hedges.
Euphorbia Helioscopia	Sun Spurge	Cultivated fields, waste places.
Euphorbia Lathyris	Caper Spurge	Woods, waste grounds, gardens; introduced.
Euphorbia Peplus	Petty Spurge	Fields, gardens, waste ground, etc.
Hedera Helix	Ivy	Woods, banks, hedges, rocks, etc.
Helleborus fœtidus	Stinking Hellebore or Bear's-foot	Thickets, bushy places, woods.
Helleborus viridis	Green Hellebore	Thickets, woods, and bushy places.
Hyoscyamus niger	Henbane	Sandy heaths, waste places, gardens.
Iris Pseudacorus	Yellow Flag	River banks, ditches, wet meadows.
Laburnum vulgare	Laburnum	Woods, copses, gardens; planted.
Lactuca virosa	Wild Lettuce	Hedges, bushy places, waysides.
Ligustrum	Privet	Hedges, copses, woods
Lobelia Dortmanna	Water Lobelia	Gravelly bottom of upland lakes.
Lobelia urens	Acrid Lobelia	Heaths by the River Axe.
Mercurialis perennis	Dog's Mercury	Woods, thickets, shady places on chalk.
Narcissus Pseudo-narcissus	Daffodil, Lent Lily	Damp meadows, copses, moist woods.
Œnanthe crocata	Water Dropwort	Banks of rivers, streams, wet places.
Œnanthe phellandrium	Water Horsebane	Shallow ponds, ditches, wet places.
Papaver Rhæas	Corn Poppy	Cornfields, waste places, etc.
Papaver somniferum	Opium Poppy	Cornfields, on chalk chiefly, waste places.
Rhamnus catharticus	Buckthorn	Hedges, copses, bushy places.
Rhamnus Frangula	Berry-bearing Alder	Wet heaths, bushy places, etc.
Ranunculus acris	Acrid Buttercup	Pastures, meadows, waysides.
Ranunculus arvensis	Corn Buttercup	Cornfields and cultivated ground.
Ranunculus bulbosus	Bulbous Buttercup	Meadows and pastures, etc.
Ranunculus Flammula	Lesser Spearwort	Bogs, marshes, heaths, wet places.
Ranunculus hirsutus	Hairy Crowfoot	Watery banks of ponds.
Ranunculus repens	Creeping Buttercup or Crowfoot	Common everywhere.
Ranunculus sceleratus	Marsh Crowfoot	Ditches, ponds, pools, river banks.
Solanum Dulcamara	Bitter Sweet, Woody Nightshade	Hedges, banks of rivers and streams.
Solanum nigrum	Black Nightshade	Fields, waste places, gardens, etc.
Tamus communis	Black Bryony	Hedges, copses, thickets, bushy places.
Taxus baccata	Yew	Woods, hedges, fields, etc., mostly on chalk.

ANTS AND THEIR WAYS.

As may be learnt from the writings of more than one ancient author, it is several thousand years since ants first commanded attention by reason of their curious habits; but it is only in modern times that any attempt has been made to thoroughly and systematically investigate these, and to ascertain what amount of truth there is in the belief that ants are endowed with a large amount of intelligence and reasoning power.

Before, however, discussing the views of recent observers on this interesting point, it will be necessary to learn something of the ordinary routine of an ant's life; to see how the nest—or, as it is technically called, the *formicarium*—is constructed, and what uses it subserves; and to find out, so far as we may, the domestic economy and relations, *inter se*, of the inhabitants.

Some ants merely excavate burrows in the earth, below a stone; others live under the bark of dead trees, and make more or less extensive galleries in the decaying wood, in some cases working up the tissues of the trees into a paper-like substance, with which to construct part of the nest; a third class raise mounds or hillocks on the surface of the earth, and live in the interior of the hill or in excavations below it; while yet another construct hanging nests in trees by glueing the leaves together; while a few others inhabit parts of living plants which they have adapted for their use. Other forms of nests might be mentioned, but, from the examples given, it can readily be imagined that just as the modes employed in constructing the "formicarium" are very varied, so are the habits of the ants themselves. It will be well, therefore, to select one particular species as the subject of our first investigations, and, having ascertained what its manner of life is, then proceed to see in what respects those of some other ants differ.

The ant which, by its wide distribution, comparatively large size, and the conspicuous nest that it constructs, seems to present itself as an appropriate subject to select for observation is the large wood or horse species, *Formica rufa* (Fig. 1). This is the one which constructs the large mounds of dead vegetable *débris* so familiar to most of us as "ant-hills" (Fig. 2). These hills sometimes attain a height of two or three feet, and contain many thousand inhabitants; but for our purpose it will be well to select a smaller and more recently founded colony. This, we can see, is a dome-shaped accumulation of dead pieces of plants, with sometimes a few stones, particles of

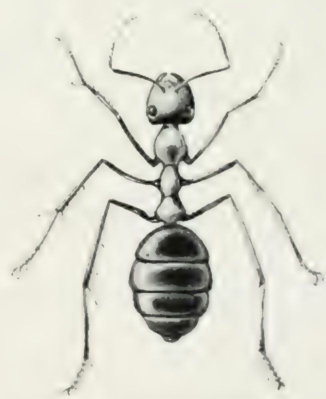

FIG. 1.—A WORKER WOOD ANT
([illegible]).

earth, and so on, intermingled. The vegetable components of the nest vary according to the situation. In a fir wood they will be found to consist almost entirely of the dead fir leaves or needles, but in other woods they may be the

stalks of dead leaves, bits of dead grass, and so forth. Whatever material is most suitable, and at the same time most easily got, is used by the ants. Whatever the material may be, it is so arranged that the dome of the nest is, to a certain extent, waterproof; at the same time, a number of doorways are left to permit of the entrance and exit of the inhabitants. These doorways communicate with winding passages and galleries in the interior of the nest, and from these again, in older nests, passages descend into the earth, where another series of chambers and galleries exist, in which the inhabitants live in winter. In recently made nests there are no underground works. These are made afterwards, and, as well as the dome, enlarged as the population of the formicarium increases. As the nest gets old the outer lower portion of the raised structure decays, becomes more solid, and is not used by the inhabitants, but abandoned to various other insects, who find in the decaying mass food and shelter. From the ant-hill, especially if it be an old one, various well-marked paths—an inch or more wide—may be seen going in various directions, and reaching to the distance of sometimes several hundred yards. Along these roads, crowds of ants may be seen hurrying to and from the nest, those that are going to it often laden with some piece of material with which to add to the structure of the hill, or perhaps with their "sucking stomachs" filled with food for the larvæ. The roads lead to the favourite hunting-grounds of the inhabitants of the nest, or to one or more new colonies; and, from the greater traffic on them near the ant-hill, are there broader and more strongly marked, as all the vegetation has died, and left the well-trodden bare earth. From the number of passengers going backward and forward upon such a road attempts have been made to calculate the number of inhabitants of a nest of *Formica rufa*, and M. Forel arrived at the conclusion that there may be as many as 500,000 workers in one nest, though in many cases the number may be 5,000 or less, according to the age of the nest.

The inhabitants of the formicarium consist of workers and fertilised and wingless females, and, for a very short time, of males and winged females. When the winged individuals (male and female) leave the pupa state, they remain in the nest for a few days, attended by the workers; but on some fine morning they come out, climb about the dome, or on to some neighbouring plant, and pair there, some, however, going off to a greater distance. At such a time the workers are in a great state of excitement, and run hither and thither, looking for the fertilised females, which are then carried into the nest. The males fly away, and, being unable to feed themselves, die in a few days, or are slain by birds or spiders, or by other ants. Many females, too, are doubtless lost when they have wandered too far from the natal formicarium. After a female has been fertilised, she takes steps to get rid of her wings, which are now of no further use. This she accomplishes by moving them backwards and forwards, and shaking them violently till they drop off. In getting rid of their wings the females are often assisted by the workers. Thereafter the rest of the life of the female is spent in laying eggs, and she takes little or no part in the work of the nest. Upon the workers devolve all the labours of the community. By them the nest is kept in repair, and added to, and the young tended. The females, and others who have not been able to go out in search of food, are fed from the supply in the sucking stomachs of the workers; and by the latter the nest is defended if attacked by an enemy. In a word, the sole end and aim of every ant seems

to be the common good, and not the welfare of the individual. In fighting they do not employ much strategy, but rush fearlessly and furiously against the enemy, biting with their powerful mandibles, or discharging—for they are not provided with stings—from the ends of their abdomens the contents of their poison reservoirs.

The duration of life of an ant after it has reached the adult stage is somewhat uncertain. The males, as we have seen, live for a few days only, but the females and workers have a longer span of life, extending, as shown by Lord Avebury, to seven or eight years at least. The period for which a formicarium may flourish varies. After a while females cease to be produced in it, and the city gradually perishes from want of inhabitants. Other causes, however, may determine the extinction, such as the failure of the food supply or the too near neighbourhood of a flourishing rival city.

In addition to its proper inhabitants, the nest of *Formica rufa* (as that of several other ants) contains other inmates. Some of these, as have been mentioned, live in the older and deserted parts of the nest, but there are others which live in the inhabited portions, and are either able to protect themselves from the owners of the nest or else live on good terms with them. In the latter case the exact relations between the host and the guest are not very clear, though in some cases it would appear that the ants obtain from their guests some sweet secretion, and in return give them protection. These guests—invited or uninvited—consist chiefly of springtails (Fig. 3), with one or two allied animals (such as mites and woodlice) (Fig. 4), and include beetles (Fig. 7), two-winged flies, and at least one

FIG. 2.—SECTION THROUGH AN ANT-HEAP, SHOWING THE PASSAGES LEADING TO THE INTERIOR.

moth. Like other species, *Formica rufa* cultivates, as it were, certain plant-lice (Figs. 5 and 6). The roads made by the ants frequently lead to trees much frequented by aphides, which live in peace under the protection of the ants. The latter, in giving this protection, are far from disinterested, for the aphides are their cows, and are regularly milked by them. If we examine a plant-louse or aphis, we shall see that it is furnished near the end of its abdomen with two little conical projections. From these it can discharge a small quantity of a sweet fluid, much relished by the ants. When an ant wishes to milk an aphis, it gently strokes the latter with its antennæ, upon which the aphis discharges a drop of the fluid, and the ant laps it up (Fig. 6).

FIG. 3.—AN UNINVITED GUEST, A SPRINGTAIL (*BECKEA ALBINOS*). (*After Lubbock.*) *This insect is very plentiful in ant-heaps.*

On the whole, *Formica rufa* is not one of the most intelligent of ants, but it has served our purpose by letting us see what a formicarium is like. It is quite easy to keep ants in captivity, especially some of the smaller species. A formicarium can be arranged by putting some earth between two glass plates fixed an eighth of an inch apart, covering them up, and surrounding them by a moat of water to keep the insects within limits (Fig. 9).

We will now pass on to another ant, whose habits are very curious. This is the amazon ant, *Polyergus rufescens*, a species not uncommon in some parts of Europe. Its nest is constructed in the ground, and covered with a dome of earth. The amazon ant is not provided with a sting, nor does it throw its poison out forcibly, like *Formica rufa*, but it is an insect of amazing courage, and gifted with a high degree of intelligence. The most remarkable fact in its history is that, being unable to construct its own nest, to nurse its young, or even to feed itself, it makes slaves of other ants, and compels them to perform these offices for it. The ants it enslaves belong to the species *Formica fusca*, sometimes called from its colour the jet or negro ant, and the manner in which the slaves are obtained is as follows:—

Having ascertained (perhaps by means of scouts) where a nest of the negro ants is situated, an army of the amazons (varying in number according to circumstances, but usually between 300 and 1,200) marches in a body to the nest that is to be attacked. The army consists of workers only, and it has no commander, though there is usually an advance guard, which, after leading for a little, retires to the rear. On arriving at the nest, the marauders rush furiously upon its guardians, overpower them, even if the weight of numbers is on the side of the assailed, and, entering, seize upon the pupæ or cocoons, and return to their own nest, where the spoil is handed over to the slaves. By them the captured pupæ are carefully tended till they arrive at the adult stage, when they, too, become slaves. In this way the supply of slaves is kept up and increased. In their expeditions, the amazons march with great celerity, and accomplish their work so quickly that in less than an hour an army may have set

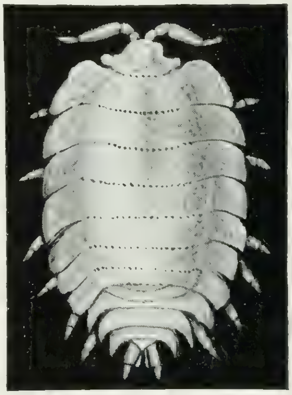

FIG. 4.—A BLIND GUEST, A TINY WHITE WOOD-LOUSE WITH A LONG NAME (*PLATYARTHRUS HOFMANNSEGGII*).

off, stormed a nest, and returned with the spoil. The masters and their slaves live on very good terms with each other, though all the work, except fighting, falls to the lot of the latter. Among so many remarkable facts as the history of this ant presents, not the least remarkable is the inability of the amazons to feed themselves. That this is not fancy has been proved over and over again; the construction of the parts of the mouth is in itself sufficient proof. When an amazon is hungry it seeks out one of the slaves, and pats it with its antennæ, whereupon the slave disgorges some of the liquid from the sucking stomach, and feeds its master. As a rule, it is only the cocoons of the workers that are carried off by the amazons when they attack a nest; the pupæ of the males or females would be of no use to them. As the pupæ of the perfect males and females are larger than those of the workers, the raiders know which to select. According to Huber, one of the earliest and most enthusiastic observers of the habits of ants, the slaves of the amazons prevent their masters from going out on a slave-capturing expedition at the time when male and female pupæ predominate, but, though it is the case that the slaves do stop expeditions on certain occasions, it is very doubtful whether Huber's explanation is correct. In addition to *Formica fusca*, *Formica rufibarbis* is also enslaved by the amazons.

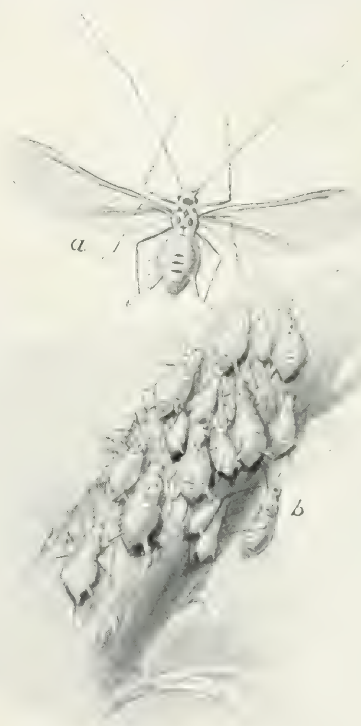

FIG 5 — WINGED AND WINGLESS APHIDES.

a, Aphis platanoides (after Claus); b, wingless aphides on a rose shoot.

Ants "farm" these insects, and are very fond of the sweet liquid they exude.

The amazon ant is not the only one that makes slaves, though it is one of the most interesting. *Formica sanguinea* is another species that employs servants, though, unlike the amazon ant, it is not entirely dependent on its slaves. The species it enslaves, which it captures in the same manner as the amazons do, are several, and it sometimes happens that, not content with making a spoil of the pupæ, the nest itself is taken possession of, and the old nest deserted in favour of the captured one. There are several other species which have similar habits, but space will not permit of these being described.

The horse ants keep herds of plant-lice, which they use as cows. Many other species have the same habit of farming insects which can supply them with a sweet secretion, but some of them practically take possession of the aphides or other insects, keeping them in or near the nest, and so shutting them up that no other ants can get to them. Amongst the ants which have this habit is a common yellow one, *Lasius flavus*, which is a great miner, and, being of a timid nature, seldom ventures above ground. Its nest

consists of galleries excavated in the earth below a stone or in a small hillock, and its food frequently consists in a great measure of the sweet liquid exuded by the aphides. The aphides that this ant keeps as milch cows obtain their nourishment by sucking the juices of the roots of plants, so that the ant has no difficulty in keeping them in its subterranean galleries, and in making the latter in places where the aphides can obtain food. This ant not only tends the aphides themselves, but is careful to preserve their eggs during the winter, and by placing them in the warmest part of the nest in spring hasten their hatching, with a view, of course, to obtain an early supply of food for itself.

The statement by some old writers that ants stored up grain in their nests was long thought to be an error of observation, and it was supposed that the larvæ or pupæ being carried in and out of the nests by the workers had been mistaken for grains of wheat or other corn, to which they bear some resemblance. Recent observations, however, have shown that the old writers were correct, and that some ants do actually collect and store up seeds of plants, which are in some manner used as food. Most of these ants belong to warm countries, and several species which inhabit the shores of the Mediterranean have this habit. As much as one pound weight of seeds has been found in a nest. The nests, which are subterranean, are made in situations where plenty of seeds can be obtained. Nor are the inmates at all scrupulous about robbing each other, and fierce fights often take place on this account.

The agricultural ant, as it has been termed, is an inhabitant of North America. Its nest is constructed in the ground, and is sometimes covered with a slight mound. For a certain space round the nest the ground is carefully cleared of all vegetation and made tolerably smooth, as are the numerous paths which lead from it. The ants are very industrious seed collectors, and may be seen toiling along their paths laden with seeds, which are stored up in granaries in the nest. In the cleared space round the nest there are frequently patches of a grass whose seeds are much sought after by the ants. It has been stated that the insects make the clearing and sow the seed of this grass on purpose to reap the crop; but evidence is yet wanting to show that the grass is intelligently and not accidentally sown. The fact remains, however, that on or round many nests there are crops of the grass, and that it is not, like other vegetation, destroyed by the ants.

The leaf-cutting ants—also inhabitants of the American continent—are too well known in some places from the great havoc they cause by destroying the leaves of certain trees and other plants.

The nest is made in the ground, and is often of very large size. In the case of one leaf-cutting species that inhabits Texas it was found that the hole left after the nest had been dug out by a man employed to destroy it was twelve feet in diameter and fifteen feet deep. This space the little creatures had occupied with numerous chambers and connecting galleries, the largest chamber (about the size of a flour barrel) being at the bottom. From the nests numerous roads lead to places where an abundant supply of the proper kind of leaves can be obtained. Some of these paths are more than half a mile long. In places that are sheltered from the sun the roads are above ground; but where they are exposed to the hot rays of the sun the road is, by some species of leaf cutters, tunnelled underground, and it is said to be sometimes carried even under streams. In the nest, in addition to the females and males (at the proper time), there are three or more forms of workers, distinguished by their different sizes and

by the work allotted to each. Those of the largest size—which may be five or six times that of the smallest, and have very big heads—are sometimes called "soldiers" (similar workers are also found amongst some other species), and they do not take part in the ordinary labours of the community, but exercise a kind of general superintendence, as well as defend the nest and their comrades from attack. The medium-sized workers are employed in cutting and carrying the leaves. These are cut upon the tree into circular pieces about the size of a sixpenny bit, and stowed away in some of the cavities of the nest. A road crowded with ants, each bearing aloft its piece of leaf, has a very curious appearance, and has suggested for these insects the name of parasol ants. An interesting intruder takes advantage of the habit of the ants, and mingles with the crowds of insects carrying home their bits of leaves. It is a little "bug," and quite inoffensive, but it secures immunity because, while its green and attenuated body looks for all the world like a bit of leaf, its dark legs cause it to be mistaken also for the ant itself (Fig. 10). The smallest size of workers remain in the nest and attend to the larvæ and pupæ. What the ants do with the leaves when they have stored them up is a matter that is still somewhat doubtful. One curious habit must not be forgotten, and that is the custom they have of closing the doors of the nest at certain hours. The doorways are carefully filled with bits of twigs, dead leaves, and other rubbish, and when thus shut the nest looks like an old and deserted one. The operation of closing the gates is long and complicated, and the ants are very careful in seeing that it is properly done.

FIG. 6.—THE ANT "MILKING" HIS "COW."

The common brown garden ant here shown is tapping the aphis with his antennæ. The aphis responds by excreting a drop of the sweet liquid previously referred to.

We must now pass on to a brief consideration of the very different habits of another class of ants, inhabitants of various tropical countries, and variously called from their habits army ants, driver ants, ants of visitation, chasseur ants, and foraging ants. These are not vegetable feeders, but eat other animals, especially insects, though often creatures of a larger size—even small mammals and birds—fall a prey to them. As by their vast numbers they soon clear out all the food available for them in a locality, they are forced to make frequent migrations, and hence have only temporary nests. They march in enormous armies, clearing before them every animal that they can master, and driving even man himself out of their path. Frequently the line of march, purposely or accidentally, embraces houses, to which they are welcomed by the inhabitants on account of the clearance that is made of the numerous cockroaches and other insects, as well as other troublesome inmates, such as rats and mice.

Certain species of these army ants which

inhabit tropical America Mr. Belt considered to be the most intelligent of all the insects of that part of the world. On one occasion he noticed a wide column of them trying to pass along a nearly perpendicular slope of crumbling earth, on which they found great difficulty in obtaining a foothold. A number succeeded in retaining their positions, and further strengthened them by laying hold of their neighbours. They then remained in this position, and allowed the column to march securely and easily over their bodies. On another occasion a column was crossing a stream of water by a very narrow branch of a tree, which only permitted them to go in single file. The ants widened the bridge by a number clinging to the sides and to each other, and this allowed the column to pass over three or four deep. These ants, having no permanent nests, carry their larvæ and pupæ with them when marching. The prey they capture is cut up and carried to the rear of the army, to be distributed as food.

Allusion has been made to the fact that ants sometimes make their habitations in suitable parts of living plants. Two instances of this may be shortly noticed. In South America there is a species of acacia which, from its strong, curved spines set in pairs, has received the name of the bull's-horn thorn. When the thorns are first developed they are soft and filled with a sweet pulp. Now, there are two species of stinging ants which gnaw holes in the soft thorns, eat all the pulp, and take up their abode in the thorn, which then becomes hard, and affords a very suitable house, the more especially as certain glands on the leaves of the tree secrete a kind of honey, which is the food of the ants. In return the ants protect the tree from the ravages of the leaf-cutting ants, which would otherwise defoliate it.

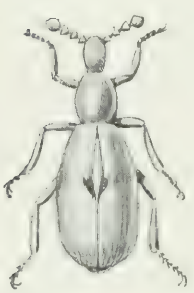

FIG. 7.—A BLIND BEETLE *(CLAVIGER FOVEOLATUS)* THAT LIVES AMONGST THE ANTS. *(After Lubbock.)*

Another species lives in the stem of the trumpet tree. This tree has a hollow stem, divided into sections at intervals by transverse partitions. The ants make a hole in the trunk, and then bore through the partitions one after the other, the cells or chambers thus formed being used to house the eggs, larvæ, and pupæ, each being kept in a different cell. This tree does not provide the ants with food; but they carry into it certain scale insects that secrete, from a pore on the back, a honey-like fluid. The scale insects get their food by sucking the juices of the tree, and live on good terms with their masters.

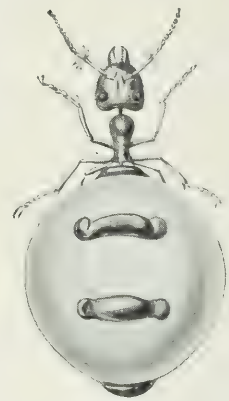

FIG. 8.—HONEY ANT *(CAMPONOTUS INFLATUS)*. *(After Lubbock.)*

Before leaving the subject, the honey ants (Fig. 8) must be noticed. They are American insects, which construct underground nests; but their chief peculiarity is that, in addition to the ordinary inhabitants of the nest, there is a special class, called honey-bearers. These live entirely in the nest, and receive the food collected by the workers, store it up in their globular abdomens—which are capable of great expansion—and regurgitate it in the form of honey when any of their comrades desire to be fed. They are, in fact, merely living honey-bags. In nests opened by Mr. McCook there were from eight to ten chambers, each containing on an average thirty honey-bearers, clinging to the roof by their feet. Another species of honey ant has been found in Australia.

It has long been well known that ants belonging to the same nest are able to recognise each other, even if they have been kept apart for months. An ant of the same species, but belonging to a different nest, is at once recognised as a stranger, and usually treated accordingly —*i.e.* it is killed. Strange larvæ or pupæ, but belonging to the same species, are, on the contrary, taken care of. But though strangers are treated as enemies, yet if pupæ be taken from a nest and entrusted to others to rear, and then restored (as adult ants) to their parent nest, they are, in the majority of cases, treated as friends. If, however, they are put in their stranger nurses' nest, they are attacked. Not content with this experiment, Lord Avebury put the ants to a more crucial test, and found that ants reared from eggs laid by a female that had been removed from the nest were recognised as friends by the ants of the nest that the female had belonged to, though not previously seen by them in any stage of their existence. No explanation has yet been made of this peculiar faculty of ants to recognise their friends and enemies.

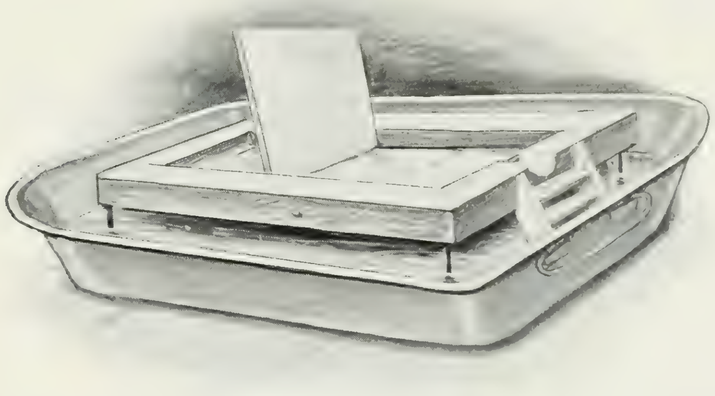

FIG. 9 A "FORMICARIUM," SIMILAR TO THE ONE USED AT THE STEPNEY BOROUGH MUSEUM.

Materials required: two sheets of glass, a photographic printing frame, and a tin dish. Water is placed in the tin dish, and a "moat" is thus formed, which confines the ants to their quarters.

The result of other experiments goes to show that, while ants are by no means destitute of kindness to their friends, yet that hatred of their enemies—that is, of every ant that does not belong to their own nest—is a stronger passion in many species.

The investigations of many observers have tended to show that ants have the power of communicating information to each other, and thus obtaining assistance in their labours. To test this, many experiments have been made, with the result of showing that such powers of communication really exist.

To test their intelligence in another manner, a number of larvæ were placed in such positions that the ants would, in their anxiety to get at them, either have to drop a very short distance or bridge a chasm by pushing a bit of paper a very little way; but the experiment failed to show that they had enough reasoning power to do either, though it would have saved a long and tedious walk by another route. In another case, a drop of only one-third of an inch would have saved an ant from a captivity of twenty-four hours, but the prisoner, though anxious

to escape, was too stupid or afraid to venture.

The general result of the experiments and observations shows that ants, though not perhaps gifted with the very great amount of "reasoning" power that some of their enthusiastic admirers have claimed for them, are yet endowed with a much higher degree of intelligence than is possessed by any other insect or articulate animal, surpassing even the bees and the wasps, which, in this respect, come next to them. It has also shown that—as might have been expected—all species of ants are not equally intelligent, and that also different individuals and different communities of the same species vary in the degree of intellectual powers which they possess. But the experiments do not enable us to say yet which species is the cleverest. Those that have been subjected to the test belong to temperate countries, and there is reason to suppose that some of the tropical ants are infinitely superior in instinctive ability

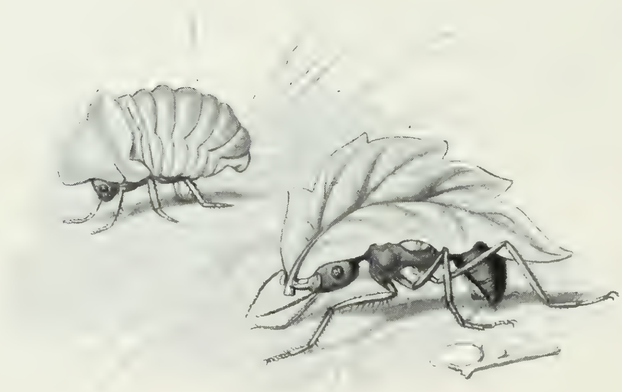

FIG. 10.—A GREEN PLANT BUG WHICH MIMICS A LEAF-CUTTING ANT AND ITS BURDEN

(After Wallace.)

STRIKING A LIGHT.

ONE of the most familiar things in a modern household is the highly necessary box of matches, and although the time may not be far distant when the common use of the electric light will enable us to dispense with them, at

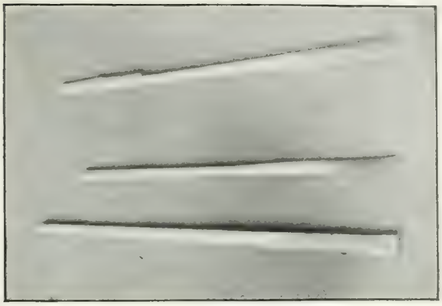

FIG. 1.—PRIMITIVE MATCHES: PROMETHEANS.

These chemical matches were like paper cigarettes; fire was produced by breaking a little glass bulb of sulphuric acid and allowing it to touch a mixture of chlorate of potash and sugar.

present matches are so much in request that it is difficult to realise a period when the householder had to find other means of procuring fire. And yet that time is not really so far back as it might seem to be. It is true that phosphorus, the chemical body upon which the match principally depends for its efficiency, was discovered by Brandt in the seventeenth century, and was used as a means of obtaining fire shortly afterwards, but as phosphorus was costly, and as the manner of using it (rubbing small particles between folds of brown paper) was exceedingly dangerous, that method of fire production never came into common use. Next came the phosphorus bottle, in which a preparation of phosphorus was contained which would inflame a sulphur-tipped splint of wood when placed for a moment in contact with it.

In the year 1805, Chancel, of Paris, introduced the so-called oxy-muriate match, consisting of a sulphur-tipped splint of wood charged with a button composed of chlorate of potash, sugar, and gum, coloured with pigment. These matches were ignited by contact with asbestos soaked in sulphuric acid, which was kept for the purpose in a small bottle. This was a very awkward arrangement, especially in the dark, where matches are most in request. The first really practical lucifer match, which was ignited by friction, was produced in 1827 by John Walker, of Stockton-on-Tees. In compliment to Sir William Congreve, of rocket fame, they were called Congreves, and in Fig. 2 is shown a photograph of one of the tin boxes in which they were sold. These Congreve matches consisted of splints of wood, first tipped with sulphur and then with a chlorate mixture, which ignited when the match was drawn between a folded piece of sandpaper. It is interesting to note that one of these boxes, containing only seven

FIG. 2.—A "CONGREVE" MATCH-BOX (1827)

"Congreves" were the first practical lucifer matches.

dozen matches and a bit of sandpaper, was retailed for one shilling.

Matches have been much improved since these early days; no longer is the user stifled with the fumes of brimstone, for, except in the very cheapest form of

matches, sulphur has been banished. Its use (owing to its great inflammability) was to carry the initial flame of the igniting composition to the wooden splint, and this *rôle* is now performed by odourless paraffin wax. A still greater improvement is found in the common use of the so-called safety match, in which amorphous phosphorus is used. These matches strike only on the box. Their tips are composed of chlorate of potash, sulphide of antimony, and glue, while the surface upon which they are rubbed is not ordinary sand- or glass-paper, but is compound of amorphous phosphorus, powdered glass, and sulphide of antimony.

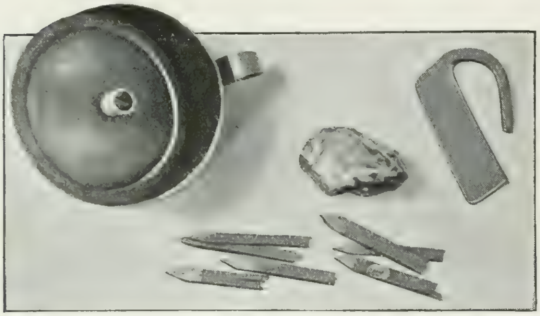

FIG. 3.—FIRE-PRODUCING OUTFIT IN THE DAYS OF GEORGE III.

Handsome prizes have been offered again and again in different countries for the invention of a match which shall strike on friction with ordinary surfaces, without any phosphorus entering into its composition. The objection to phosphorus is the terrible effect it has upon the health of the workpeople in the factories. It is true that amorphous phosphorus is free from this objection, but it is considered a drawback from the efficiency of a match that it will not strike on anything but its own box. As a matter of fact, these matches will take fire if drawn rapidly across a sheet of glass, the peculiar friction thereby aroused being sufficient to generate sufficient heat to ignite the chlorate composition.

As we have seen, the first friction matches were the Congreves. Immediately before the Congreves there were the "Prometheans" (*see* Fig. 1), whose career was only short-lived. Their value as instantaneous lights was due to the circumstance that a mixture of chlorate of potash and sugar (a compound rich in carbon) at once deflagrates if touched with a drop of strong sulphuric acid, owing to the liberation of a gaseous compound of chlorine and oxygen, which may be regarded as a supporter of combustion. These chemical matches consisted of a kind of paper cigarette, to which was fixed a small quantity of the sugar and chlorate composition, and in which there was a small glass bead or globule containing sulphuric acid. The breaking of the latter, by compressing the match with a pair of pliers or between the teeth,* liberated the acid, which at once performed its chemical function.

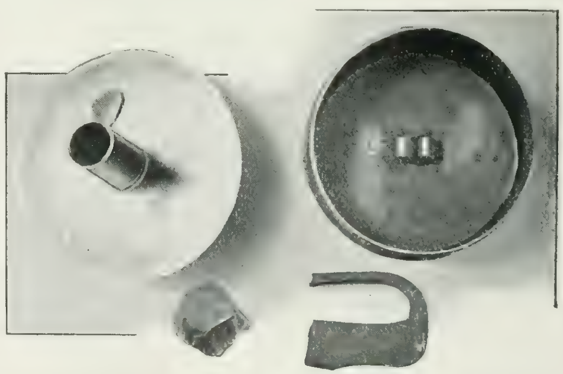

FIG. 4.—AN OLD TINDER-BOX, WITH FLINT AND STEEL.

Not the least interesting method of

* The man who thus struck a light with the first "Promethean" seen in Cornwall had reason to regret it. The superstitious tin-miners before whom he carelessly exhibited the new chemical toy were no doubt sufficiently impressed with the wonder, for they dragged the chemist thrice through a pond as a wizard. Ever afterwards he was rather prejudiced against *al fresco* popular demonstrations on the curiosities of science.

FIG. [illegible].—HOW THE FIJI ISLANDERS OBTAIN FIRE.

A piece of hard wood is rubbed [illegible]

obtaining an instantaneous light by chemical means was that illustrated by the so-called "philosophical lamp," devised in the early part of last century by Dr. Johann Wolfgang Döbereiner. It consists usually of a cylindrical glass vessel, about six inches high and four inches in diameter, in which, attached to the under surface of the movable metallic lid, there is hung a bell-shaped glass, which reaches rather more than half-way down, while there is suspended inside it a mass of metallic zinc. Above, the bell-shaped glass becomes tubulated, and at pleasure an opening can be effected between the tubed portion and the external atmosphere. Now, by filling the glass vessel fully half-way up with water, and then introducing the bell-shaped glass, it is evident that, if the little tap is closed, the air in that glass will be under a certain degree of pressure. Let the tap be opened, however, and the contained air will rush out until the water rises to a uniform level both inside and outside the

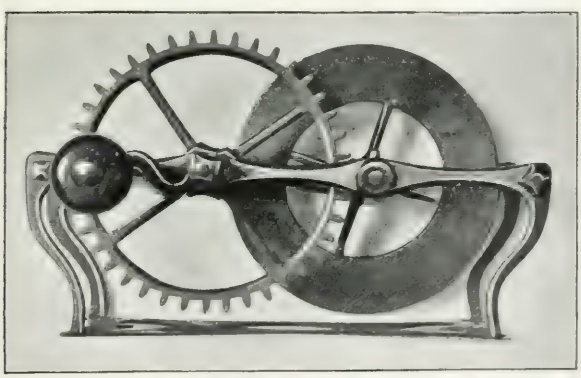

FIG. 6.—STEEL MILL USED IN COAL MINES FOR STRIKING A LIGHT, PREVIOUS TO THE INVENTION OF THE SAFETY LAMP.

bell. If the water is now acidulated with sulphuric acid, chemical action will be set up, the zinc liberating a quantity of hydrogen gas, which will accumulate in the bell; and by turning on the small tap, that gas, hitherto under pressure, will rush out, and will burn if a light is applied to it. But instead of lighting it in that way, let us place a small mass of metallic platinum, in its spongy condition, within a short distance of the escaping jet of

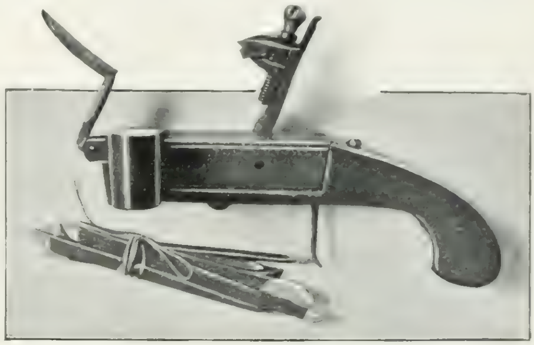

FIG. 7.—A RELIC OF STAGE-COACH DAYS.

This fire-producer had a flint-lock action. A bundle of the "matches" used is shown beneath it.

hydrogen. Almost instantaneously the platinum sponge will begin to glow and become brilliantly incandescent, and the jet of hydrogen will then take fire and burn with its comparatively non-luminous flame. Following Döbereiner's instructions, we have struck a physical light from certain apparently unpromising materials; and, for the benefit of the uninitiated, we shall now throw a little mental light upon the process by which it was struck or obtained. Let it be observed, then, that spongy platinum has the peculiar power of abstracting oxygen gas from the air, and storing it up in its pores in a highly concentrated form. If that gas and hydrogen be brought within the range of their chemical affinities, union will ensue with more or less energy. In this case, the hydrogen finds the oxygen in such a condition as to favour the immediate union of the two elements; heat results from the chemical union, and very shortly it reaches the condition of bright, glowing incandescence which is necessary for ignition of the still

escaping jet of hydrogen gas. This lamp is even yet in occasional use on the lecture table of the professional chemist, and it is a beautiful example of the

FIG. 8.—A CHINESE FIRE-MAKING OUTFIT.
Steel, flints, and a bag of tinder.

application of science in our endeavours at "striking a light."

It may be remarked here that a self-lighting gas burner, made on the same principle as that upon which the Döbereiner lamp depends for its action, was introduced a few years ago, and was exhibited in one or two of the London shop windows. But it never seems to have gone much beyond that stage, possibly on account of the difficulty of keeping it in the needed state of precise adjustment, except by expert hands.

The use and value of the classical flint and steel in "striking a light" have long been known, although the practical employment of the process referred to is somewhat unfamiliar to the present generation. Every boy knows, however, that he can call forth at pleasure a brilliant shower of fiery sparks from a dry pavement of coarse sandstone or rough asphalte, providing that his shoes or boots are well shod with iron or steel. Such showers are frequently seen when a powerful horse vigorously sets his shoulders to the work of drawing a heavy load over slippery granite or whin paving-stones. In these, and many more or less similar instances, the process of "striking a light" admits of a thoroughly scientific explanation. It is simply friction. Draw the hand rapidly along the table, or down the sleeve of your coat, and heat will be felt. Rub any two hard substances—or, indeed, any solid substances—together, and there will also be heat. If the operation is continued with sufficient energy, the heat will increase in intensity until it is visible in the form of "fire." It is this which is displayed when the flint is struck against the steel, or against another piece of flint. To put it very briefly, the mechanical energy exerted in producing the friction is transformed into heat, which actually becomes so intense as to set fire to the minute particles of iron or steel that are separated from the mass by the violence of

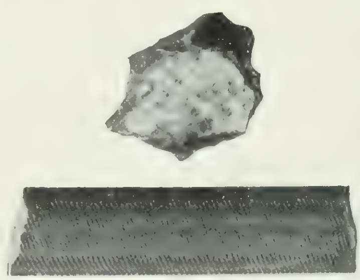

FIG. 9.—FLINT AND STEEL USED IN WALES.

the action. Of course, there must be oxygen gas present, otherwise no sparks of light will be emitted at the moment of exerting the friction. If flint and steel be struck against each other in a vacuum there is no light produced, but the particles of steel thrown off, if afterwards examined by the aid of a microscope, show distinct signs of having been in a

molten state. But in order to get a permanent light from the evanescent shower of sparks just spoken of, it is necessary that the incandescent particles of steel should be allowed to come into contact with easily ignited material, which will burn slowly—such a substance, for example, as the tinder which is produced by the imperfect combustion of linen or cotton rags, or, better still, the substance called *amadou*, or German tinder, which is a peculiar preparation of several species of fungi belonging to the genus *Polyporus*. This smouldering tinder may then be touched with a sulphur-tipped wooden splint, which at once bursts into flame.

Photographic illustrations of several different forms of flint and steel are given. Fig. 3 is the complete apparatus for producing light as used in this country in the reign of George III. The tinder-box is about four inches in diameter and one inch deep, and it contains the tinder upon which the sparks from the flint and steel fall. This initial fire was carefully fostered by the breath, and from it the sulphur-tipped splints, or matches, were lighted. When the tinder was done with, the fire was smothered by means of a loose-fitting cover of metal, which will be seen within the box. Fig. 4 shows another tinder-box of a slightly different pattern. Fig. 7 gives an extremely interesting application of the flint-lock pistol action to the purpose of procuring a light, and was a contrivance used on the stage coaches, and generally in the open air, where an ordinary tinder-box could not be conveniently employed. Just below the tip of the flint, instead of the usual pan to hold the priming powder is a little box filled with tinder, which takes fire directly the trigger is pulled. We may feel certain that an unloaded pistol would often be used for fire production when other means were not at hand. As in other cases, the fire from the tinder would be used to inflame sulphur-tipped splints of wood.

Fig. 9 shows a simple steel arrangement, apparently part of a half-round file, which, in conjunction with the piece of flint shown with it, is said to be still in use in certain remote parts of Wales. A Chinese light-producing kit forms the subject of Fig. 8, the steel being very much smaller and more ornamental than the English pattern, and the flints being represented by pieces of that variety of silica which comes under the head of chalcedony. A paper bag, full of black tinder, accompanies the steel and the little stones.

But it is not even necessary to use the steel at all, as it is quite possible to get light by friction in even a less promising way. For example, it is even possible to render two quartz pebbles distinctly luminous by rubbing them together in the dark; then, again, if a small rock-crystal have one of its faces briskly drawn over the face of a large crystal of the same material, both heat and light are produced. On the authority of a gun-flint maker, it has been stated that flint-chips, if thrown violently down upon touch-paper* lying on a flagstone, will develop such an amount of heat as will induce ignition in that combustible material; and from this it may be inferred that there will not be much difficulty in "striking a light" if two flint-stones, with good edges, be violently struck against each other over a mass of dry moss on which sulphur is thinly scattered in very fine powder. Many primitive tribes of mankind obtain fire by somewhat similar means. The wild Eskimo generally obtain it by striking pieces of quartz and iron pyrites together, allowing the resulting sparks to fall upon moss which has been well dried and

* Touch-paper is made by immersing bibulous paper (like blotting-paper) in a solution of nitre, and then drying it carefully.

vigorously rubbed between the hands; and the aborigines of certain parts of Eastern Asia, and especially of the islands of Borneo and Sumatra, produce it by striking together two pieces of split bamboo. Of course, it should be noted that amongst the woody tissue of a bamboo-stem there are deposited myriads of small crystals of quartz, and thus the method in question does not seem so very extraordinary.

But fire may also be obtained by the sudden compression of air in a confined space containing some very combustible material. For this purpose the beautiful experiment with Mollet's pump, or the ordinary fire syringe of the lecture room, may be employed. It consists of a small metal or glass cylinder, in which a closely fitting, solid piston works. It is readily noticed that heat is developed by rapidly forcing down the piston along the cylinder, and if a small bit of German tinder be fixed to the piston and the action then be performed, the tinder will be ignited sufficiently to inflame a sulphur match. If, instead of the tinder, a pellet of cotton-wool which is moistened with ether or bisulphide or carbon be used, a flash of light may be obtained inside the cylinder, and can be seen, if the latter is made of glass (Fig. 10).

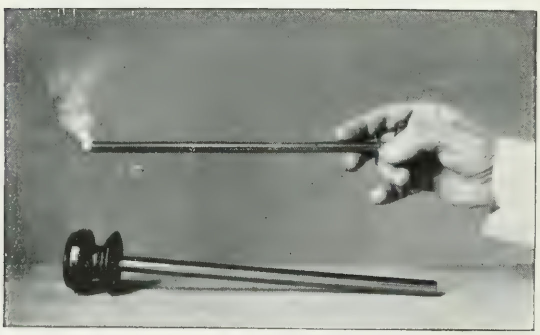

FIG. 10.—THE FIRE SYRINGE.

In a small metal or glass cylinder a tightly fitting piston works. If the piston be rapidly worked the heat resulting from the friction is sufficient to set alight a piece of tinder or a pellet moistened with ether or bisulphide of carbon.

Of the many varied methods of employing friction to obtain fire among savages in both hemispheres, we have left ourselves no room to speak with any detail; but a simple experiment may indicate how such people may turn the principle to account in their native homes. First, let the reader note the effect produced by the rapid friction of a flat brass button against a piece of soft, dry wood—an old and familiar experiment. Then let him take a bit of dry wood a few inches long, and rub it vigorously by one end upon a wooden surface—say, a clean, dry floor. In a very few seconds the heat developed will be sufficiently great to ignite a pellet of dry phosphorus if the rubbed end of the stick is simply laid against it. Primitive tribes certainly do not possess phosphorus as one of their conveniences, but they have the wherewithal to produce light if they possess any wood, and particularly if they have both hard and soft woods. As an example of the mode of getting fire by rubbing two

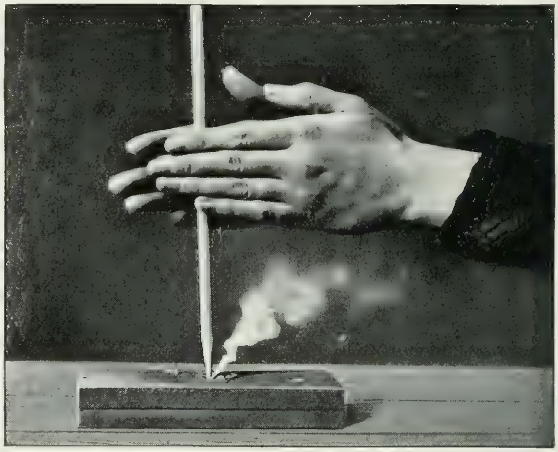

FIG. 11.—FRICTION BETWEEN HARD AND SOFT WOOD

The stick is twirled rapidly between the hands.

pieces of wood together, as shown in Fig. 5, the following may be quoted by Captain Drayton, regarding the Kaffirs of South Africa :—

"Two dry sticks, one being of hard and the other of soft wood, were the materials. The soft stick was laid on the ground, and held firmly down by one Kaffir, whilst another employed himself in scooping out a little hole in the centre of it with the point of his assagai; into this little hollow the end of the hard wood was placed, and held vertically. These two men sat face to face, one taking the vertical stick between the palms of his hands, and making it twist about very quickly, while the other Kaffir held the lower stick firmly in its place. The friction caused by the end of one piece of wood revolving upon the other soon made the two pieces smoke."

Professor Tyndall, in his well-known work "Heat a Mode of Motion," also refers to this method of obtaining fire by friction between hard and soft woods, and shows that if a rounded stick be rapidly revolved by the hands in a block of the same material, as shown in Fig. 11, heat is soon evolved. He writes: "It is easy to produce smoke with it, but not fire." Mr. Darwin tried his hand on it at Tahiti. "The fire," he says, "was produced in a few seconds; but to a person who does not understand the art it requires the greatest exertion, as I found, before at last, to my great pride, I succeeded in igniting the dust." It seems obvious that the simple apparatus shown would be far more effective if the rotating rod of wood were crowned with a weight, or some kind of pressure were applied to it. This is done in the far more effective experiment shown in Fig. 12—where the rod is fitted with a grooved wheel which, by means of a cord, is connected with a larger wheel not shown in the picture. Professor Tyndall, to whom this experiment is also due, writes of it that a wooden pin, three or four inches in length, is rapidly reduced to charcoal powder; but, even under these altered conditions, actual flame is extremely difficult to obtain.

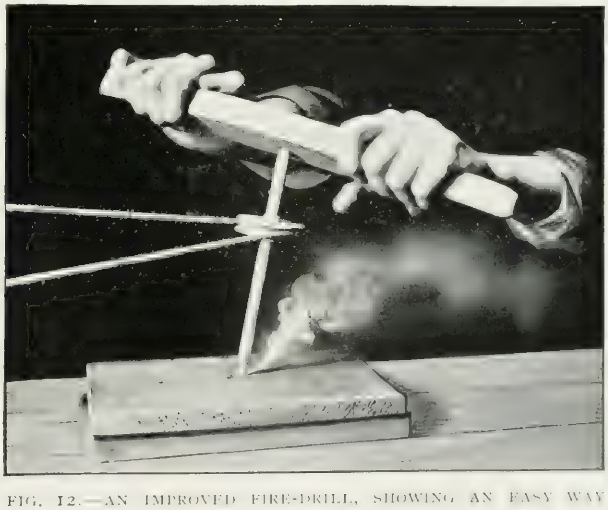

FIG. 12.—AN IMPROVED FIRE-DRILL, SHOWING AN EASY WAY OF ROTATING THE STICK.

In addition to a rapid rotary motion, pressure can be applied at the top of the revolving stick.

GETTING HOT.

BY WILLIAM ACKROYD, F.I.C.

SOME years back, in the main street of one of our busy towns, anyone might have observed a very curious fact—the lower halves of several large plate-g'ass windows were cracked from side to side. A glance was sufficient to show that the cracks were not produced by the stray missiles of street Arabs, for they had not that radiating or star-like arrangement which is generally seen in such cases, but, instead, consisted of a large split proceeding from one side to the other, with one or two minor cracks branching therefrom (Fig. 1). To account for this curious and highly inconvenient phenomenon was a sore puzzle to many of the good folks about; some there were, however, more knowing than the rest, who arrived at a sensible and satisfactory explanation, thereby proving what is perhaps demonstrated every day—nay, every hour—that science is only, to use the words of Huxley, trained and organised common sense.

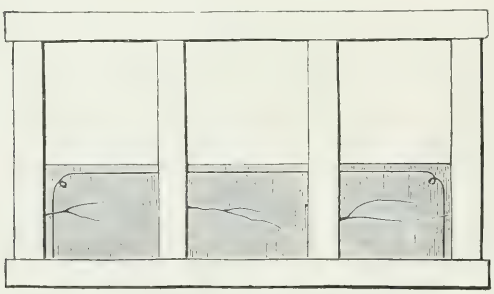

FIG. 1.—A PROBLEM IN CRACKED WINDOWS.

It was midsummer. The windows of the shops where these cracks were to be seen faced the south, and were therefore exposed to the full glare of the sun's light and heat. The lower halves of the windows—*i.e.* the cracked parts—were painted, on the inside, of a dun colour, and by two in the afternoon had become quite hot to the touch, whereas the upper and unpainted halves were only slightly warmed. Herein lay the secret.

When a substance is being warmed, it expands, grows bigger in every direction, and the following simple experiment (Fig. 2) well illustrates the fact:—A rod of copper or brass, A, just fits lengthways between the ends of the metal gauge, B, and its diameter is such that one end of it fits tightly into the hole, C, when neither is the hotter—that is, when both gauge and rod are of the same temperature. If, now, the rod, A, be heated in a gas flame, it will be found that it can neither be thrust into the hole, C, nor adjusted lengthways in the gauge as before, for this heating has made it larger in every direction, so that it is too thick to go into the round hole and too long to fit into the gauge. This fact, which is here so well shown, may be proved in many other ways equally simple. I will give one, and then try to show that the fact is usually recognised in the arts, and taken advantage of or allowed for, as the case may be. Let a flask, A (Fig. 3), be quite filled with water, and then fitted with a cork through which a glass tube has been previously passed. As the cork is being thrust tightly into the vessel the water will rise in the tube, say to *a*. Now place the flask in a basin of hot water. The first thing noticed is the fall of the liquid column to *b*. The process of warming the flask has made it expand, its capacity has been increased, and the water in the tube falls to take up the increased space. This does not last long, for soon the water within becomes warm, and now it expands likewise, and there

is a race in expansion between the water and the flask, in which the latter has got the start. The water expands the faster of the two, however, so that soon the liquid column has reached *a* again, passed it, and arrived at *c*.

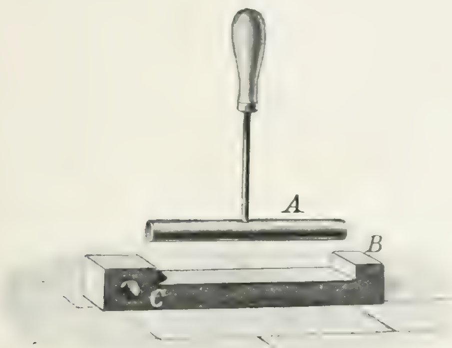

FIG. 2.—ILLUSTRATING THE EXPANSION OF METALS.

A, a rod of copper or brass; B, a metal gauge into which the rod A will fit exactly, when cold; C, hole into which the rod fits when cold. If the rod be heated it becomes too long to fit into the gauge, and too big to fit into C.

And now for an example or two where the artisan makes use of, or an allowance for, this nearly universal law. The cartwright who wants to fit the iron rim tightly on to a cart-wheel takes the rim and heats it in the fire until it is red hot, thus making the rim much larger than it would be in a cold state. The rim is now pressed on to the wheel, cold water is poured on, and, resuming its usual size in getting cold, it clasps the woodwork in a vice from which there is no escape. Again, the reader may have noticed that in a tramway the ends of the iron rails are not in contact; there is a small space between each to allow the metals to expand on hot days. If this allowance were not made, if the metals were in contact end to end on a cold day, then, when it became warmer, Nature, relentless, and as if in scorn at man's work, would tear up those rails, sleepers would be riven up, and bolts bent as if in play. What we have imagined in this last instance is the nearest approach to what took place when the plate-glass windows were broken. The glazier fixed the windows as if they had been small panes, where the amount of expansion is very minute indeed, and they were fixed in a rigid framework that would not give way. The painter, on his part, in his ignorance of certain principles I shall presently explain, put on a colour which led to the glass being strongly heated in the sun's rays. What followed? The plate-glass was heated and expanded; the frame of the window tried to restrict that expansion, and in the struggle the weaker had to give way, not doing so, however, until it was irremediably injured. The condition of the window-panes was not unlike that which the late Dr. F. Guthrie imposed upon specimens of glass of various shapes in a research on the fracture of such objects.* The accompanying six illustrations (Fig. 4) exhibit some of his results. The first, *a*, shows that when a round plate of glass is placed on a thick soft cloth, and is pressed in the centre by a round cork, it cracks radially—that is, the lines of fracture spread outwards from the centre. The remaining figures, *b*, *c*, *d*, *e*, and *f*, show what takes place when plates of glass of peculiar shape are heated in the centre with an air-gas burner. We have

FIG. 3.—EXPANSION OF WATER.

A, a flask of water, [illegible]

* "On the Fracture of Colloids." "Proceedings" of the Physical Society of London, Vol. III., pp. 76–81.

here a difference of temperature between the borders and central areas, which produces an internal strain that relieves itself by fracture. Of this series of breakages, *e* and *f* most nearly approach the conditions met with in the window-panes. The rigid frame in the one case corresponds to the cold and comparatively non-expanding rim in the other; and there being a similarity in the conditions to which the glass in the two cases is exposed—viz. an expansion of a central area restricted by the comparatively non-expanding framework—there is a likeness in the cracks produced.

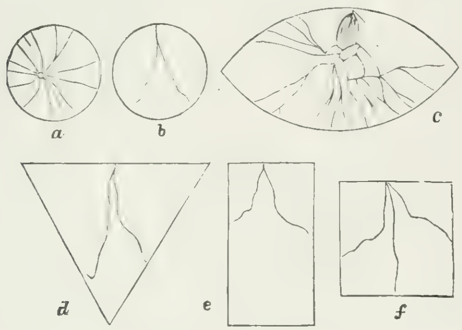

FIG. 4.—GUTHRIE'S EXPERIMENTS ON THE FRACTURE OF COLLOIDS.
The direction of the cracks in these plates of glass illustrates different methods of treatment.

What was a mystery then, is now a mystery no longer, for it will be clear that the agent at work was the sun. We see, further, that some influence has apparently passed across 92,890,000 of miles of space from the sun to the earth, and is here capable of making things hot; this influence, whatever may be its nature, electro-magnetic or otherwise, is termed *radiant heat.* The heat in substances like the dun-painted glass, water, and rod of metal, we speak of simply as *heat* or *sensible heat.* Light and radiant heat are one and the same thing, and the only qualification to such a statement is the physiological one that our range of vision is limited, so that, while what we call a light ray is also a radiant heat ray, we may have a ray which is still radiant heat but is inappreciable to the human eye as light. These points are best brought out by the following comparisons.

Light is bent in passing from one medium to another; so is radiant heat. The simplest proof of this is the action of a burning lens, which, when held in the sun's light, bends the heat-rays, just as it bends the light-rays, to a focus where objects may be burnt. It may be shown with one of the glasses of a pair of spectacles adapted for long sight, for if such a convex glass be held some inches from the back of the hand, so that the image of the sun is projected on to it the heat will be very sensibly felt. Larger lenses are of course, more powerful for this purpose; and in times past effective scientific work has been accomplished with them, as when Priestley discovered oxygen. In the polar regions Dr. Scoresby often lit fires and did other wonderful things with a lens made of ice. These facts, then, plainly show us that heat radiating from the sun is bent like light when passing through suitably shaped media. The question now arises, To what extent is it bent?

In working out this problem many interesting facts have been discovered. When a solar beam is passed through a prism it is evident that a sorting of the different kinds of light is effected, each ray being gathered unto its kind—red to red, blue to blue, &c., as shown in Fig. 5, where colours are represented by their initials. Class distinctions here reign supreme, and it is found that *dark heat-rays* have precedence of the red light-rays, just as red light comes before the orange, and the orange before the yellow, in the solar spectrum. In the effort to get through the prism the dark heat-rays have the least trouble and the violet rays the most. Suppose, now, we were to employ a prism of rock salt (P, Fig. 5) in producing a solar spectrum, and were then to place a delicate thermometer in different

parts of the spectrum, we should find that the highest temperature is registered a little beyond the red light, and that we should get lower and lower degrees upon testing each part of the spectrum on the way to violet. It would seem, then, that the infra-red part of the spectrum is the most favourable for getting hot in, and that there is less and less warming power as we proceed towards the violet end. Let us regard these constituents of the solar beam now a little more as they affect our organs of sense. The infra-red rays have no effect on the retina; they are invisible—hence the phrase we have employed to designate them, *dark heat-rays*. When we come, however, to the red, if we were to concentrate this part of the spectrum on to the skin we should feel the sensation of heat still, and the same rays passed into the eye would give one the sensation of light. Here, then, heat and light are identical, and we employ either one or the other term according to the nature of the effect on our sensory organs.

The physical basis of the dark heat-rays and of the more easily bent light-rays is the same, and is usually regarded as a wave motion of that all-pervading medium, ether, which connects atom to atom and star to star. The length of these ether waves is measured by the physicist in fractions of an inch or of a millimetre. Thus, the rays which produce the sensation of light have wave-lengths not greater than $\frac{1}{34000}$th of an inch (red light), nor less than $\frac{1}{64000}$th of an inch (violet light). But as the metric system is universally adopted by scientific men, it is usual to speak of the lengths of ether-waves in ten-millionths of a millimetre, a unit technically known as the *tenth-metre*—thus a ray of 7,604 "tenth-metres" is $\frac{7604}{10000000}$ths of a millimetre in length. The usual standards of reference are the *Fraunhofer* lines, the dark lines in the solar spectrum, whose general positions are indicated in Fig. 7. Angström's measurements of these lines are given in the following table:—

Solar lines.	Wave-lengths in tenth-metres.
A	7.612
B	6.875
C	6,568
D_1	5.900
D_2	5.894
E	5,274
b	5.177
F	4,865
G	4.310
H_1	3.972

To return to our consideration of the heating power of different parts of the solar spectrum. It will have been noticed from previous remarks that the heat-rays are crowded together, as it were, at one end of the spectrum and gradually spread out at the other. In thinking over this matter, it appeared probable to the well-

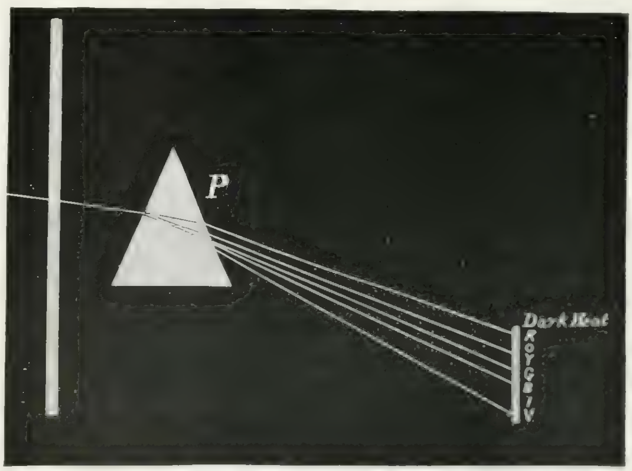

FIG. 5.—POSITION OF DARK HEAT-RAYS IN THE SPECTRUM.

P, a prism through which a ray of light is made to pass; R, O, Y, G, B, I, V, the colours into which the ray is split up, here represented by their initial letters.

known American investigator, Dr. J. W. Draper, that if a given series of red rays were collected, and their warming power tested, it would be equal to that of an equivalent series of violet rays. He accordingly tried the following experiment. In a visible spectrum, he collected all the light of wave-lengths between 7,604 and 5,768 together, and also all that of wave-lengths between 5,768 and 3,933, the former belonging, of course, to the red half of the spectrum, and the latter to the half ending in the violet; and he found their warming power to be equal, as determined by a delicate electrical instrument termed the *thermopile*. This result one might thus express:—Any series of ether-waves in the solar spectrum, the difference in length of whose extremes is a certain number of tenth-metres, has the same warming power as any other series of ether-waves with the same difference of extreme wave-lengths. In the case of Dr. Draper's experiment it is seen at a glance that the differences of wave-lengths in the two series employed are approximately equal:—

Tenth-metres.	Tenth-metres.
7,604	5,768
5,768	3,933
1,836	1,835

We may now profitably resume our comparison. *Light is reflected from a polished surface; so is radiant heat.* In the case of light, proofs constantly present themselves, because of the sensitiveness of the eye to light, and many simple proofs of the reflection of heat might be devised based on the sensitiveness of the skin. Get the tinker to beat out a small sheet of "tin" into the shape of a can-bottom, say a foot in diameter. A polished concave reflector will be thus obtained for a few pence. Let there be a good fire in the grate, and take up a position at one end of the room where the heat rays are not felt, although their path is not obstructed. Now turn the concave side of such a reflector towards the fire, but bent sufficiently on one side to allow any rays that may fall on it from the fire to be converged on to the face. When this is done a feeling of warmth is experienced, showing clearly that the heat of the fire has been brought to a focus *by reflection*, just as light would be under similar circumstances.

Just as light may be absorbed, so may radiant heat. In every coloured body, more or less of the light falling on it is absorbed, and the remainder, which produces the sensation of colour, is reflected; and it is plain that if the light absorbed is that which will produce the sensation of warmth when directed on to the skin, then we have here likewise an absorption or drinking in of radiant heat. The heat-rays of a sunbeam are also absorbed by many substances that are transparent, and ice is one of these; for although we have seen that, if a lens be made of ice, sufficient heat is passed through and converged to a focus to set many things on fire when the lens is held in the sun's rays, we likewise know that a few heat-rays are stopped by the ice, and therein melt it in the most beautiful and systematic manner. Tyndall has shown that when a bundle of rays are passed through a slab of ice, beautiful six-petalled flowers are revealed, each with a bright spot of empty space in its centre (Fig. 6). In this manner, no doubt, glaciers, bergs, and other accumulations of ice are melted. They may, however, be melted in a much more expeditious manner by a process precisely similar to that by which the window-panes we have spoken of were over-heated. There the dun paint captured a large amount of the sun's heat-rays by absorption, became hot, and imparted a great part of its heat to the glass it was in contact with. So, in like manner, if the ice were covered with a coloured substance greedily absorbing

heat, and sufficiently thin for the heat to pass through or radiate from it, the underlying ice would soon disappear. The skater may frequently have noticed twigs, brown leaves, and straw sunk many inches in the ice. Being ready absorbers of heat, these fragments of vegetation have soon become warm in the sun's rays, and slowly sunk into little icy graves of their own making, and probably at the very next frost the water lying over them has been frozen. We have then seen a leaf or a twig in the middle of a solid block of ice, and have probably been as much puzzled to account for its presence there as the ancient geologists were bothered about insects embedded in amber. This melting of ice by means of coloured vegetables lying on them may have performed a most important part in the history of the world. In 1870 the Arctic explorer Nordenskjöld paid a visit to Greenland for the purpose of seeing which were the more suitable in the Arctic regions for sledging purposes, reindeer or Eskimo dogs. He and a companion had one long excursion out on the "inland ice," and everywhere they noticed vertical cylindrical holes a foot or two deep and from a couple of lines to a foot or two in width. In some cases the holes were so near each other that it was impossible to find room between them for the foot. Nordenskjöld invariably found at the bottom of them a grey powder, which had evidently been the means of stopping the sun's heat in the first instance, and afterwards of melting the ice. He remarks :—"When I persuaded our botanist, Dr. Berggren, to accompany me in the journey over the ice, I joked with him on the singularity of a botanist making an excursion into a tract, perhaps the only one in the world, that was a perfect desert as regards plant life. This expectation was, however, not confirmed. Dr. Berggren's keen eye soon discovered, partly on the surface of the ice, partly in the above-mentioned powder, a brown, poly-cellular alga, which, small as it is, together with the powder and certain other microscopic organisms by which it is accompanied, is the most dangerous enemy to the mass of ice so many thousand feet in height and hundreds of miles in extent. This plant has, no doubt, played the same part in our country; and we have it to thank, perhaps, that the deserts of ice which formerly covered the whole of Northern Europe and America have now given place to shady woods and undulating corn-fields." But nine years before Berggren's observations, the late Dr. Robert Brown, during his researches in the same desolate region, had shown that Arctic ice was often coloured brown by the presence of Diatoms, and was often seen to be honeycombed, having at the base of the cavities accumulations of these coloured microscopic objects.*

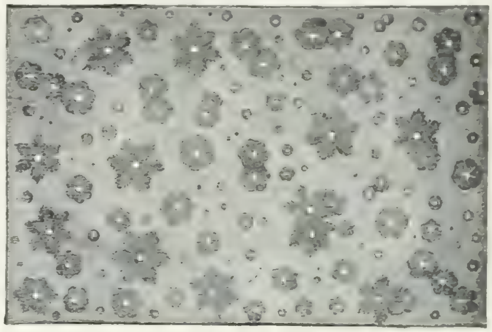

FIG. 6.—ICE FLOWERS.

These flowers only become visible to the eye in a slab of ice when the ice is beginning to melt.

It is plain that in the brown alga, yellow straw, black twigs, and dark bodies generally, we have substances, like the dun paint, which readily absorb the heat coming from the sun or any other heat-source, and lead to the melting of ice on which they may rest at a much faster rate than when it is bare. A kettle coated

* Brown: "The Physical Structure of Greenland" ("Arctic Papers of the Royal Geographical Society," 1875). "Arctic Manual," p. 311.

with soot will sooner heat the water within it than another kettle that has been highly polished on its exterior. And now we may point out that these highly absorbing substances are exceedingly useful; for when they have received heat they give some of it out again, and thus warm the substances around them which cannot themselves absorb the sun's rays so readily. Nature's great rule of reciprocity is here strikingly illustrated: a good receiver of heat is a good giver, and gives lavishly of its abundance to the bodies which are around it; and, on the other hand, a bad receiver of heat parts but tardily with what it has absorbed. A clean glass flask of hot water is longer in growing cool than one whose surface has been lamp-blacked, because the lamp-blacked surface radiates heat better than the surface of bare glass; and the same flask filled with cold water would be longer in growing warm if put in the sunshine than it would be if its surface were lamp-blacked, because the lamp-blacked surface is a better absorber of heat than that of the bare glass. Hence, to keep the heat for a length of time within the flask, the worst thing we could do would be to cover its surface with a deposit of lamp-black or soot, and the best we could do would be to surround it with a worse absorber and radiator than the glass itself. For the latter purpose we should find the hairy coverings of animals very effectual, and probably better still those patent coverings for boilers, cylinders, etc., which inventors, taking a hint from Nature, have devised to economise the fuel employed by the manufacturer.

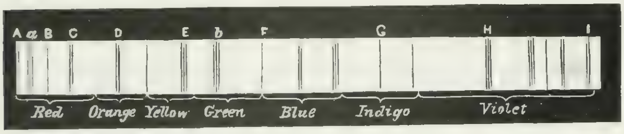

FIG. 7.—SOLAR SPECTRUM, SHOWING THE FRAUNHOFER LINES.
These dark lines in the spectrum of the sun are revealed when solar light is spread out by the prism of the spectroscope.

Another most important element we have now to take into consideration is distance, it being a matter of everyday experience that a substance may be warmed much sooner near the fire than one which is a long way off it. *Just as light obeys the law of inverse squares, so does radiant heat* (Fig. 8). This precise law tells us the exact proportions of heat which two like surfaces in every respect receive at various distances; if one of them, say A, be one yard off, and another, B, nine yards away, we know that B would receive only $\frac{1}{81}$st part of the heat received by A. By means of the law of inverse squares we can easily calculate the comparative amounts of heat falling on two surfaces at different distances from the house-fire, and in precisely the same manner we can ascertain the comparative amounts of heat that each wandering planet receives from the great central focus or fire, the sun. The astronomer thus knows the warming power of the sun's rays when they reach each of the planets, and is able to furnish us with the following results, from which the reader will see that a square of planetary surface, say a mile in area, receives nearly seven times more heat on Mercury, and a thousandth less on Neptune, than it receives on the Earth:—

Planet.	Warming power of Sun's rays.
Mercury	6·674
Venus	1·911
Earth	1·000
Mars	431
Jupiter	·036
Saturn	·011
Uranus	·003
Neptune	·001

For getting hot, then, under the most favourable conditions there must be close

proximity to the heat-giving or radiating body, and the recipient must have a very good heat-absorbing surface. If the giver and receiver of heat be in absolute contact, then the colder substance may get warm, even although it be an indifferent absorber. A poker is sometimes left in the fire, and the end in contact with the red-hot cinders soon becomes red-hot too. The heat at the red end flows towards the colder parts of the bar of iron, so that it would be dangerous to seize it a short distance from the red-hot part. The process by which the heat has passed from the hotter to colder parts of the bar is termed *conduction*, and this quality of conductivity is possessed in very various degrees by different substances, so that we have good, bad, and indifferent conductors of heat, just as we have absorbers

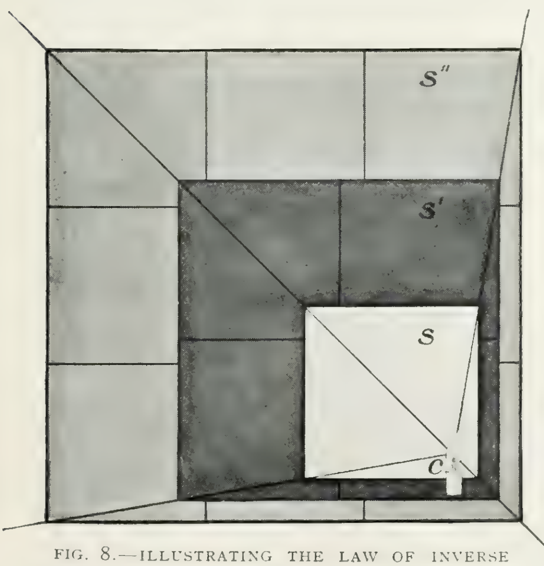

FIG. 8.—ILLUSTRATING THE LAW OF INVERSE SQUARES.

The screens S, S′, and S″, at distances 1, 2, and 3 from the candle C, receive its light and heat. At unit distance all the radiant energy falls on a unit of surface ; at twice the distance the same area only receives one-fourth, and at thrice the distance only one-ninth the amount of heat falling on S.

of every kind. There is a number of simple devices for showing this difference of conductivity; the following is one of them :—A metallic trough has a number of holes made along one side. These are closed by corks through which are passed rods of various substances—as copper, wood, and glass. If now each of these rods be dipped in melted wax or tallow, they become coated with a thin film of that substance, which solidifies as soon as they are withdrawn. Let the rods now be placed in the apparatus shown in Fig. 9, with their unsmeared ends reaching into the vessel, and next fill the box with boiling water. The extent to which the heat is conducted along the different rods is roughly seen by observing the distances to which the wax or tallow is melted along them. In this way we should find out that the metals are the best conductors of heat. The different conducting powers of the rods can be made visible more strikingly still by painting them with the double iodide of copper and mercury, a substance which changes in colour from red to dark brown at so low a temperature as 70° C., so that the difference of conductivity is shown by the distance the dark colour extends along the several rods. More refined experiments would teach us other facts respecting conductivity, as that the metals themselves vary in the degree of facility with which heat is permitted to flow along them, silver being the best and bismuth about the worst of metallic conductors ; that heat flows much more easily through certain substances in some directions than in others ; and that there is a close analogy between heat conductivity and electric conductivity, the best conductors of heat being the best conductors of electricity.

We must leave these matters now, however, and in conclusion direct our inquiries to the question : What is heat ?

During the eighteenth century it was thought that, when anything was being warmed, an invisible substance—which philosophers were never able to weigh—was being made to enter it. They called this hypothetical body *caloric*, and they were firmly persuaded that when "caloric"

was made to leave, say, a stone, the stone became cold, while if the caloric was made to enter the stone and store itself amongst its ultimate parts, then the stone became hot. In process of time, however, some facts were discovered which this hypothesis of caloric thoroughly failed to explain. If there existed such

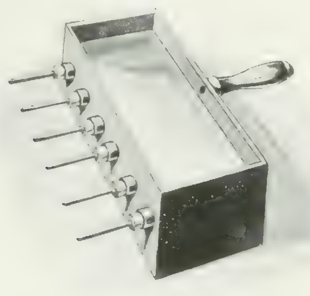

FIG. 9.—AN EXPERIMENT TO SHOW DEGREES OF CONDUCTIVITY OF HEAT IN VARIOUS SUBSTANCES.

The rods are smeared with tallow, and the degree of conductivity is shown by the extent to which the tallow is melted.

a substance as caloric, then, like all other matter, it would be impossible to entirely destroy it or produce it from nothing. Heat, however, was plainly produced when a smith took a piece of metal and beat it with a cold hammer on a cold anvil until it was too hot to touch. Where had the heat come from? The question became more startling still when Count Rumford found that, in boring brass cannon, the heat developed by the friction, even when the shavings of metal cut out by the borer weighed only a few ounces, was sufficient to make two and a half gallons of water boil. The quantitative results in these experiments showed that the amount of heat produced is proportional to the work done. And conversely, in the experiments of Hirn, it was shown that when heat is made to do work in a steam-engine, part of the heat disappears, and the proportion apparently destroyed is proportional to the work done by the engine. From these facts it follows that heat is not a substance, but a something very nearly related to the swinging motion of the hammer, the rotating motion of the borer, and the up-and-down rotating and revolving motions of a steam-engine; it is, in short, an exceedingly rapid motion of the molecules of a body. When, therefore, the bearing which supports a rotating shaft becomes very hot for want of oiling, we figure to ourselves a transmutation of this visible motion of rotation into an invisible molecular motion which we term heat. In making a substance hot, then, by whatever means we choose, we are agitating its molecules more and more, and we may carry this on until the molecules vibrate so quickly that they affect the ether which surrounds them, and so send off a continuous series of ether-waves—the so-called radiant heat—which, rushing against the skin, may give us the sensation of heat, or, coming against the retina, the sensation of light. If the motion of the ether particles be taken up by some substance other than these organic membranes, we have an absorption of heat similar to that we saw in the case of the dun paint. The dun paint may, again, communicate its molecular motion to any substance like the glass that it may be in contact with. Thus it appears the various facts concerning heat may be readily explained by this theory. But while the scientific antiquary sees that the mechanical theory of heat is more commodious than the ancient one of caloric, he is strongly impressed with the fact that its builders have largely availed themselves of the material presented to their hands by the demolition of the old caloric theory; he recognises the old stones of fact, although in many instances they have been redressed; and the main difference between past and present century work he traces to the more powerful and precise instruments, mental and material, which are now being employed by the scientific craftsmen in rearing and perfecting their work.

THE SCENERY OF THE SHORE.

OF all the sights that meet the eye of the habitual dweller in an inland district of a country so little diversified by abrupt physical features as our own, there is none that charms him so greatly at first sight, or retains its peculiar attractions unchanged for so many years, as the view of the sea-shore. The portion of the coast-line that first greeted his unaccustomed eyes may possibly have been some picturesque fragment of our western shore, where the dizzy cliffs plunge sheer into the depths of the Atlantic. Or it may be a part of our softer eastern coast, where league after league of yellow sand borders the fertile farm-lands like golden fringes. Or, what is far more likely, the silent sea first dawned upon him as he floated out upon it, over the spreading bosom of some vast estuary, where the sight of the slow-receding shores, and the ever-widening waters, awed him into his first true idea of its limitless expanse. Wherever it may have been, it was certainly to him a turning-point in his life, a day of strange emotions, unfelt before, and never to be forgotten.

Even to the constant dweller upon the sea-coast, familiar with the shore from his earliest boyhood, it is doubtful if the sight ever becomes trite or stale. He lives at the very boundary-line between life and death. On the one side is the solid land, clothed in its immobile pall, the apparent embodiment of stability and permanence. Not a mound, not a cliff, but bears the visible impression of wearing the same features that marked it at its origin. Whether seen full and clear in the brightest sunlight, or caught vaguely, half shrouded in mist and fog, the same familiar outlines are ever recognisable, for the hand of time moves lightly upon these self-same cliffs, the end is sure, and time is content to wait.

How different the mobile sea, never the same in its aspect for a single moment! Its surface, as far as the straining eye can reach, is in a state of continual movement. Even when the air is at its stillest, and all else seems asleep, its hissing rollers chase each other over the shallows, and its billows dash themselves into white foam upon the cliffs. From the shore to the long, level horizon it is instinct with a multitudinous, all-pervading life.

This wonderful contrast, seen nowhere else, forms perhaps the main foundation of our keen enjoyment of the view of the sea-coast, and gives it its most peculiar charm under every aspect. But the main source of our delight as we wander along the sea-shore is undoubtedly the endless variety in the coast scenery, afforded by frequent changes in the form and contour of the land, and the contrast of this rise and fall of the land with the never-varying level of the ocean.

The coast of Britain yields us these pleasant changes in endless variety. In one spot, as at Bournemouth, the shining beach of sand, wet with the ebbing tide, stretches out far into the ocean, till at low water the sea and land seem to melt into one. In another spot, as at Dover and at Beachy Head (Figs. 1 and 2), the dizzy cliffs seem to plunge at once sheer into the ocean depths. In one locality the blue waters run up in little creeks and bays far into the land; in another, a grassy point, marked by its white-washed lighthouse, juts out into the waves. Here the cultivated fields overhang the water's edge; there the shore-line is fringed by the long dunes of blown sand that guard the grassy "links" loved by the leisurely golfer.

To the mere searcher after the picturesque, perhaps the most patent character of the familiar sights of the shore is their unchangeableness. In quiet weather how well-defined seems to be the boundary between the land and sea! The daily pulsation of the tide steals merely a narrow fringe of beach, which the land ever regains at the ebb. The long billows that break on the beach with a noise like thunder, scarcely disturb the incoherent sands below them, or at most leave merely a picturesque pattern of minute wavelets on the sandy floor. The heaving rollers that cover the sides of the cliffs with a veil of fleecy foam, rise and fall aimlessly and ineffectually.

Photo: T. C. Hepworth.

FIG. 1.—THE TOP OF BEACHY HEAD.

But the sea is a creature of moods. Let our friend venture out when a wild north-easter is blowing, when the fierce gale lashes the waves till the sea is a chaotic mass of tumultuous billows, almost buried from sight in the clouds of hissing foam. If he can bear the brunt of the weather, he will see that the waves no longer keep the bounds that restrained them when the day was calm. Driven onward by the mad blast, they hurl themselves in wild disorder upon the beach. Mounting up the shelving shallows, they reach up to the sandy dunes, tear them away piecemeal, and hurry them out to sea. The strong breakwater, built of gigantic blocks, seemingly hard as the hardest iron, cemented and clamped together into a solid mass, trembles from end to end under each thud of the ponderous billows, and the heaviest block that is broken loose is hurled aloft as if it were a feather. The sloping "talus" of rounded fragments that guarded the face of the neighbouring cliff is now covered by the breakers, and the loose stones are uplifted and dashed against the naked face of the cliff with the noise of artillery.

Now, for the first time, he begins to realise the fact that he is looking upon a mighty contest—the battle between the sea and land—one of which the ultimate issue can hardly be doubtful. It is impossible that any cliff, any shore, can endure such a terrible assault as this for ever; and this assault must of necessity be renewed at every gale. The fragments of rock these billows loosen and pound together are the visible proofs of the certain dissolution of the edge of the land.

The coast of Britain affords everywhere abundant proofs of the destructive nature of these repeated attacks. The whole eastern coast-line of England is being cut away by the waves at the rate of from two to four yards in the course of the year. The old sites of the ancient ports of Ravenspur, Cromer, and Dunchurch are now buried far beneath the waters of the North Sea. At Weybourne, in Norfolk, there is now water enough to float a line-of-battle ship where once a village stood upon a cliff fifty feet high. The southern coast is being cut away almost as rapidly, and the waters are aided in their work of destruction by the frequent landslips that bring the shattered rocks within reach of the billows. The site of old Chichester and its ancient cathedral is now far out at sea. Year by year the paths of the coastguardsmen retreat inland before the advance of the waters. The celebrated Goodwin Sands, which have been the scene of many a disastrous shipwreck, were once low-lying but fertile and perfectly habitable land. According to some authorities, they formed the site of an island called Lomea, the *Infera Insula* of Roman writers. At any rate, they represent a considerable encroachment of the hungry sea upon the patient, long-suffering land.

Nowhere in Britain is the violence of this perpetual onslaught, and the swift and certain advance of the sea, more clearly exhibited than on the extreme north coast of Scotland, and the outlying islands of the Orkneys and Shetlands. In many localities in these wild regions, even on the calmest day, the tide runs with such swiftness that the sea-line is white with spray. In the fierce gales that sweep in from the wide ocean to the west, the spectacle is sublime and terrific. The tumultuous billows of the Atlantic, arrested by the land, pile themselves one over the other, and hurl their united waters in solid sheets up the faces of the perpendicular cliffs to the height of more than a hundred feet. Driven onward by the tempestuous wind, which tears fragments of stone from the faces of the precipices and flings them far and wide over the pastures, the waves dash themselves up the narrow voes and creeks with which these coasts are pierced. So great is their force that they rend off sheets of strata from the living rock, and pile them in heaps at the shoreward end of the creek, like the *débris* of enormous quarries. The effects produced in these regions by the combined action of the wind and waves are almost incredible. Dr. Hibbert describes solid masses of rock, containing from 200 to 300 cubic feet, as being lifted from their native beds by the waves, hurled to distances of from 30 to 90 feet, and ultimately shivered into fragments. The well-known "Grind of the Navir" is a mighty chasm which has in this manner been hollowed out of solid porphyritic rock within the memory of man. Every little seam of softer rock is at once eaten into by the waves and rapidly scooped out, first into a cavernous hollow, up which the sea washes with the noise of thunder, and finally into a narrow voe, dark with its overhanging cliffs.

The coast scenery of these northern islands, more especially where they are composed of the old red sandstone, is wonderfully striking and picturesque. Towards the Atlantic face perpendicular cliffs, from five hundred to a thousand feet in height, their bases ever bathed in a long line of white foam, and their upper edges fretted into countless stacks and pinnacles of rock in every stage of formation and decay. Tinted with bright hues of red and yellow, their sides ribbed with the horizontal lines of rock-stratification and scored by innumerable joints, they rise up majestically into the air, the silent but awe-inspiring witnesses of the irresistible might of the ocean.

The unique character of this coast scenery is the natural outcome of the physical fact that the strata out of which these cliffs are carved are slightly-sloping beds of alternate sandstones and shales, traversed by countless joints and cracks. The waves penetrate into these weaker portions, and loosen the rock in cubical slabs. These are soon washed off, and the cliff falls away in great vertical slices, thus preserving its striking perpendicularity. Where these vulnerable spots are more than usually abundant the cliff is cut down to the sea-level in vertical chasms, and giant, square-sided stalks are cut off from the mainland, and stand isolated, like colossal chimney-stalks of dizzy altitude. The most remarkable of these is the Old Man of Hoy, a vast, square-sided column of coloured sandstone six hundred feet in height, and a well-known landmark to the mariners of these storm-vexed shores.

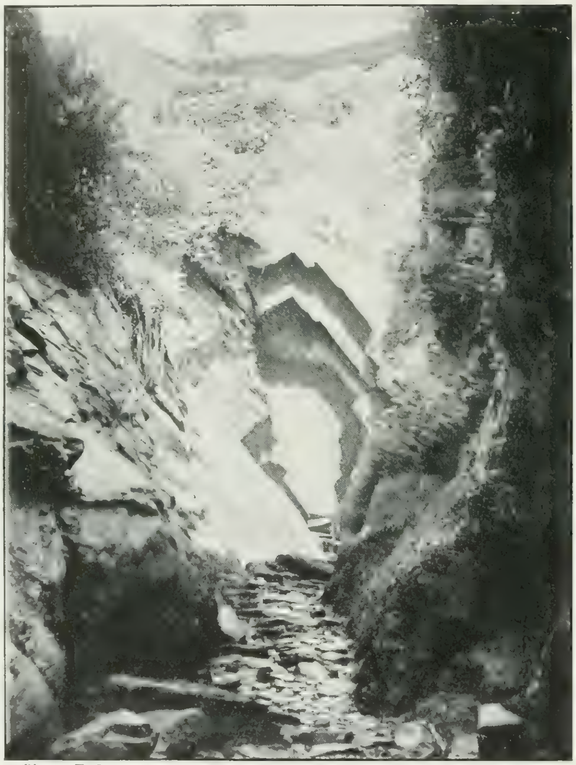

Photo: T. C. Hepworth.

FIG. 2.—BRIERY CAVE, DEVONSHIRE; SHOWING HOW A "COOMB" IS FORMED.

The sea has tunnelled into the soft rock, forming a cave, and the roof has partly fallen in. The rest of the roof will go, in time, and the cave will become a glen or "coomb."

But it is not only the sandstone rocks which suffer from the ravages of the ocean on these islands. Their peculiar arrangement of bedding and jointing allows the waves to act with greater rapidity; but, in truth, nothing is proof against the attack of the waters. The hard mica-schist, the indurated quartz-rock, and even the intractable granite, waste in their turn, each with its own special form of weathering. The larger islands are slowly broken up; the small ones melt down into mere clusters of fantastic rock-pillars, which, rising here and there far out at sea, are likened by the fanciful mariner to the pipes of an organ or a fleet of ships in full sail.

Wherever the coasts of the British Islands are exposed to the full sweep of the Atlantic waves the rapid devouring of the shore is especially noticeable, and the scenery approximates somewhat to that of the Orkneys and Shetlands. The west coasts of Scotland and Ireland are gashed to a jagged outline throughout. The narrow creeks, the steep cliffs, the rocky islets, return upon us again and again in endless succession, but varied and modified by the ever-changing nature of the rocky block which the ocean carves.

He who rambles along the margin of such iron-bound shores as those just mentioned, when the tide is low, cautiously picking his way over the projecting ridges, and coasting the numberless little

Photo: T. C. Hepworth.

FIG. 3.—BEACHY HEAD. LOW WATER.

creeks and pools, can hardly help asking himself why the waves do their work so capriciously. Why does this long ridge of black rock, almost buried from sight at its outer end by its mat of barnacles, rise so much above the general surface, running like a squat wall far out to sea? This little creek, running far back into the land, fringed with its growth of bladdery weed that rises and falls rhythmically with the motion of the waves—why is it here? The answers to these questions are not far to seek. Let the observer examine the rocks before him, tapping them with his hammer. He will discover for himself, in the course of a few minutes, that the rock of which the projecting reef is composed is far harder than the strata around it; or it is solid and compact, formed of a single bed. while they are jointed, thin-bedded, or shaley. Its present prominence is due to the simple fact that the waves found it more difficult to erode it than they did to wear down the surrounding beds; and its prominence with respect to these will be found to be pretty much in direct proportion to the amount of the sum total of its resistance to aqueous erosion, as compared with the general average of the rocks around.

The little bays and pools will be found to owe their origin to the same cause. A softer set of beds, a group of thin-bedded shales, a more jointed assemblage of sandstone—anything, in fact, that allowed the waves to act with greater rapidity, will be found to have been the prime cause of the commencement of the depression, which is daily widened at the expense of the harder rocks which bound it.

If he now study a geological map of Britain, he will see for himself that he has in this simple manner discovered the cause of the vast majority of the repeated changes in the coast-line. The capes and promontories are, as a rule, formed of the harder rocks; the bays and inlets are eroded in the softer material.

The hard "basset," or upturned edge of the well-known chalk formation, runs diagonally through England from Dorset to Yorkshire. Where it strikes the southern shore we find the promontory and cliffs of St. Alban's Head, and where it touches the German Ocean on the Yorkshire coast we find the headland and cliffs of Flamborough. Where its in-lying edge that surrounds the Weald comes upon the Straits of Dover we find the dizzy mass of Shakespeare's Cliff; where it strikes the Channel is the bold foreland of Beachy Head. Just lately Shakespeare's Cliff has been the cause of a mild sensation. A rumour was set on foot that a fiat had gone forth from the War Office that it should be demolished because it interfered with certain defensive works in process of formation. The durability of the harder chalk is apparently the only cause that has preserved the Isle of Wight from destruction. It forms the rocky backbone of the island, and runs out to sea in the picturesque stack of the Needles.

The western edges of the British Islands are mainly composed of very ancient and most highly indurated strata. Where these reach the shore we find promontory, cape, and cliff in abundance. The peninsulas of Carnarvon and Pembroke owe their existence to the fact that they are composed of some of the hardest rocks in Britain. The promontory of Cornwall would long since have been buried beneath the waters of the Atlantic but for the fact that it is a land of granite and intractable metamorphic rocks, upon which the sea has comparatively little power.

In obedience to precisely the same general law, the bays and inlets are worn out of the softer strata. The shallow inlet of the Solway Firth is cut in the clays and sandstones of the poikilitic and

lias. The long inlet of the Bristol Channel has been plainly hewn out of a long basin of soft secondary rocks that once lay between the hard sandstone ranges of South Wales and Devonshire. The straits of Spithead and the Solent have been washed out of the soft sands and clays of the tertiaries, and so also has the long estuary of the Thames itself. The Wash and the Humber are cut out of the soft oolites that lie within the escarpment of the chalk. The estuaries of the Forth and Clyde have been carved out of the soft beds of the higher carboniferous. Countless other instances might be adduced. Every indentation and projection of the coast-line is an unmistakable monument of countless ages of erosion.

This erosion, so powerful in its ultimate effects, is not carried on in every locality at a corresponding rate ; and, indeed, anyone who is at all familiar with coast scenery is almost certain to arrive at the conclusion that only a very small fraction of the shore is being cut away. Every fragment that falls from the cliff eroded by the waves is at once carried away, and the denudation is evident ; but by the side of every headland in Britain are countless little bays with soft beaches, that remain permanent and unaffected by the most severe storms, the mightiest waves spending all their force upon the sloping shallows. The old bay of the Wash is now almost filled up by the material brought down by the rivers, and which the sea has failed to carry away. The northern shore of the estuary of the Thames is formed by miles of soft, sandy, and muddy matter, upon which the waves seem to have no tangible effect.

Let the reader who feels this difficulty visit some little bay small enough to bring all the phenomena before his eyes in a single view. At each end of the bay are the two steep cliffs that overhang the deeper water, and against which the waves dash their fiercest. He will soon see that each long wave as it comes in from the sea breaks its original force against these cliffs, and that the parts of it which enter the bay itself have their speed arrested. Their motion decreases in the shallowing water, and dies wholly away at the landward margin of the bay. A few minutes' observation will enable him to perceive that the form of the bay is almost precisely that given by the bounding headlands to the entering wave. Remove the headlands, and the waves would begin to destroy the beach ; alter the form of the entering waves, and they will rapidly cut the soft shore-line to their new shape.

Where, as in the English Channel generally, the waves strike the shore obliquely, a new set of phenomena make their appearance. At each advance of the wave it lifts forward the sand and shingle obliquely up the beach. On its retreat they roll back into the sea, not along the line the wave impelled them, but perpendicularly to the shore-line, under the influence of the force of gravity. In this way they are gradually driven forward along the coast-line, and are gradually worn down as they proceed, their places being continually filled by fresh material. To protect the easily eroded coast-line, the dwellers in these parts drive rows of piles into the beach. These piles, or groins, as they are called, arrest for a time the advance of the pebbles, but the sea soon heaps them up to the height of the groin, forms a new beach a little more distant from the land, and the travelling of the stone goes on as before. The island of Portland is such a groin, which has been formed by Nature itself. The travelling beach behind it is the well-known Chesil Bank, which protects the coast of Dorset. The erosion of the island itself goes on with wonderful rapidity. When it is wholly cut away, the Chesil Bank will disappear, and

the Dorset coast be again given over to the fury of the waves. At present this bank is from 20 to 43 feet high, nearly 200 yards wide, and about 16 miles long. It is composed of sand and fine gravel at its western end, the larger particles being found as we proceed eastward.

Along the coast of Britain generally, the set of the currents is usually along shore, and the *débris* worn from the cliffs or brought down by the rivers is carried out to sea to the sandbanks of the Goodwins, the Dogger, and the like. In spots sheltered from the action of these currents there is an accumulation of sandy matter, and the land for a time seems to gain upon the sea. Of this nature are the "links" of our northern districts, protected by their dunes of sand. The formation of these peculiar hillocks is very simple. When the tide is out and the wind is blowing off the sea, the dry sand is lifted by the gale a few inches above the level of the ground. The bushes and bunches of grass that fringe the land untouched by the waves are sufficient to arrest the advance of the sand, which falls in little mounds along that line. Every gust pushes forward a little more sand, which is forced to the summit of the long ridge of heaps, and, falling over, rolls down on the opposite side. In this way a long mound of dunes is formed parallel with the shore, having its height proportioned to the average strength of the local gales. Within it, towards the land, are the "links" themselves, ridged with the broken-down relics of former dunes, in one spot verdant with short, sweet turf, in another ablaze with golden gorse.

Photo. [illegible]

FIG. 4.—ON THE CORNISH COAST; SHOWING HOW THE SEA CUTS INTO THE LAND.

This inlet is the termination of a rocky valley down which runs a small but impetuous stream. See also Fig. 5.

Sometimes these "dunes" reach a height of between 200 and 300 feet above sea

level. Or, instead of this, they may be pushed inwards, the sand covering the once fertile land and ultimately spoiling it, from the farmer's point of view. It is estimated that on the French coasts in the Bay of Biscay the average annual progress of this "sandstorm" is between 50 and 60 feet. In Scotland the coasts of Nairn and Elgin are remarkable for their long stretches of sand dunes.

But, like the sandy beaches, these long stretches of blown sand accumulate only in the sheltered spots on low-lying coasts —we should not expect to find them on the cliff-bound southern coast of the Isle of Wight, for instance—protected by the configuration of the neighbouring coasts from the full force of the ocean current. They derive their materials mainly from the waste of the outlying cliffs where the real work of degradation is incessant. Let us return to these, and see how this work is being carried on.

When the tide is at its fullest the cliffs are fringed by a wide stretch of white breakers, running for some distance out to sea. When the tide is low this coast-fringe is exposed, and is seen to be a wide, rocky platform stretching outward from the base of the cliffs (Fig. 3). As we pick our way painfully over its rugged floor we behold everywhere the proofs that this platform is in reality the work of the waves. The base of the cliffs is smoothed by the stones that have been hurled against it, and is worn out into overhanging hollows and deep, dank caves. On the floor of the platform itself the might of the waves is quite as plain. Its surface is worn into countless heights and hollows, and its seaward edge into a multitude of small creeks and promontories. Little thought is needed to perceive that this platform has been cut bodily out of the cliffs themselves, which must once have stretched seaward to its outermost edge.

This sea-worn platform is met with wherever the coast is being eroded with more than ordinary rapidity, running like a wide selvage along the edge of the land. It is very strongly marked on the east coast of Scotland, on the iron-bound shores of Fife and Forfar. Nor is its origin far to seek. In the open sea the waters simply rise and fall in successive undulations. It is only in shallows or when obstructed by the edge of the land that these undulations become waves of translation, and press forward the loose material that lies in front of them. Even this power is restricted to a few feet of the surface of the waters. It ceases at a very moderate depth; and it is very doubtful if the forward movement of the waters a few feet below the surface is sufficient to impel stones and boulders over the bottom with sufficient force to erode the sea-floor to any appreciable extent. The distance at which the waves cease to act effectually is gauged with tolerable accuracy by the depth of these coast-platforms. Sometimes several of these platforms are bared at the lowest tides, rising like a series of terraces in successive steps towards the shore. The deepest shelf has plainly been cut out by the waves of the lowest neap-tides, the highest platform by the spring-tides in spring weather, and the intermediate steps by intermediate tides. In all cases the method and results are precisely similar. The shoreward edge of the water cuts its way in a horizontal groove landward into the cliffs, the unsupported rocks above fall into the waters, there to be pounded to fragments and hurried off by the currents into the deeper hollows. The seaward edge of the land is thus rapidly worn down to a tolerably uniform level, and the rock-bound coast is fringed by a broad and slightly sloping platform running out to sea.

The coast scenery of the shores of Scotland is frequently marked by a peculiarity

rarely discernible in that of the southern parts of Britain. In many districts the line of cliffs appears for a time to retreat from the actual shore-line, running back into the body of the land, and leaving a broad margin of level ground, often many miles in width, between it and the beach. This flat ground—the "Carseland" of the Scots—is, as a rule, highly fertile, and forms perhaps the best arable land in the country. Its resemblance to an old sea-platform, like those we have been describing, is apparent to the most superficial observer. On a first examination, however, this view of its origin appears untenable, for it is soon apparent that its general surface is several feet above the level of the highest spring-tides; but an extended examination places it beyond question that these inland cliffs must at one time have been reached by the sea-waves. We soon recognise in them all the features of the true sea-cliff—the overhanging precipice; the frequent cavern, now scarcely visible through the veil of tangled bushes and weeds that hides the entrance; the little creek, where the rocks are soft, now green with short, sweet herbage; the old reef, where the rocks are hard, rising out bare and grey through the brown soil of the cornfield. When, finally, we pick up an abundance of half-destroyed sea-shells in the grass-grown sand that fills the crevices of these old sea-cliffs, our conviction becomes a certainty. There is no escape from the conclusion that we are looking upon an ancient shore-platform, now raised high and dry above the reach of the waves.

One such solid platform, the surface of which is now about 25 feet above the level of the ocean, can be traced almost continuously round the coast of Scotland. On the east coast it forms the floor of the fertile carses of Falkirk and Gowrie; on the west coast its relics are apparent in nearly every sheltered bay. From about 120 feet above the sea-level down to its present average position, we find these terraces at various heights. For this phenomenon it is clear there can be but one explanation: the island of Britain must have been elevated again and again, and these successive platforms must have been the work of the sea-waves during the successive pauses in the general upheaval.

But if upheaval of the land has actually taken place, analogy would lead us to suspect that there may also have been depression. Though the proofs of depression are not so patent to the ordinary observer as those of upheaval, they are fully as conclusive. In many districts where our shores are shelving—as near the mouths of the Tay, the Humber, and the Severn—after a more than ordinarily tempestuous day we see quantities of peaty-looking matter cast up by the sea, and the entire beach blackened with its triturated fragments. If we examine any of the larger pieces of this black-looking matter, we find that it is made up of dark clay, filled with peat, pieces of wood, mosses, equisetums, and the like—the characteristic vegetation of cold, moist ground. This is washed up by the sea from old forest beds, now submerged below the level of the waters. In excavations for docks and bridges these ancient floors are cut into by the workmen. Everywhere we find them to be composed of some thickness of peaty matter, in which lie the prostrate trunks of the oak, the fir, and our common forest trees, the old roots of the monarchs of the forest still in place; and scattered on the old forest floor lie the acorns and the hazel-nuts that dropped from the trees of this ancient forest, together with the sub-fossil antlers of the deer and elk that roamed its glades. The whole is usually buried under a much later accumulation of sand and clay, full of our commonest sea-shells, laid down by the sea-

waters that have overspread the site of the old forest since its submergence.

Of the extent of these repeated upheavals and subsidences we can as yet form no adequate idea. The total variation of level in this part of the world, even since the advent of man in these regions, probably amounts to several hundreds of feet. The fragile shells of the common shell-fish of our present coasts may be collected unbroken from the old sea-beaches of Moel Tryfaem, high up on the flank of Snowdon; and peat, turf, and the stumps of the forest trees of forgotten lands may be dredged from the centre of the German Ocean.

In this way, by repeated upheavals and subsidences, every portion of the earth's surface is brought for a time within the narrow zone where, as we have seen, the shore-waves pare it down to their average level. Every part of the land surface, and, in all probability, every part of the sea-floor, becomes in its turn the shore-line, and is subjected to the wear and tear of the waves of "the wild and wasteful ocean." When there is a lengthened pause in the general movement of the earth-crust in any region, then the waves have time to cut a fringing platform. The width of the platform recognisable around our coasts affords us some idea of the length of the present pause in the general movement of the earth-crust in these regions. The carse platforms of the northern coasts mark former pauses, when the land stood much lower, relatively to the sea-level, than it does now. These elevated terraces have, probably, their counterparts below the present level of the sea. They are, however, not only invisible to us because of the superincumbent waters, but are hardly to be detected even by the most careful soundings. This is inevitable, for the inequalities of the sea-floor are being

Photo: J. C. Hepworth.

FIG. 5.—A ROCKY VALLEY ON THE CORNISH COAST.
Compare with Fig. 4.

continually smoothed away by the deposition of sediment from rivers and from the waste of the cliffs, which is distributed by the sea-currents into all the deeper hollows.

But these pauses in the movement of the earth-crust are, most probably, rather the exception than the rule. In a continued movement of upheaval or depression there would be no time for these terraces to form. Again, though a terrace might appear to be permanent during any period of movement, as the land rose or sank gradually, if the movement were sufficiently slow the terrace would rise and fall with the movement of the land, the waves cutting down and lowering the old terrace as the land rose, or cutting forward and upwards continuously as the land sank. All these causes tend to give a gradual slope to the sea-bed, and would lead us to expect a gradual deepening of the sea in proportion to the distance from land. This, indeed, we find to be the case, and to such an extent that the floor of the sea is to all appearance a continuation of that of the land. Where the slope of the latter is small, the sea is shallow; where the land-slope is steep, the water deepens rapidly.

If we study a good chart of the coasts of Britain we shall find that, as a rule, the present coast-platforms stretch out to sea no farther than the line where, on a stormy day, the white breakers begin to form. The floor of the sea beyond this line is below the depth at which the waves have any power to move foreign matter with sufficient force to erode it. A wide fringe of shallow water surrounds these islands, marking the places where the rock has been worn away when the land was higher. Beyond this the waters gradually deepen—nowhere, however, to any great depth on the eastern and southern coasts. An elevation of a couple of hundred feet would leave dry all the floor of the German Ocean and English Channel, and unite these islands to the Continent. This elevation, as we have seen, has probably more than once taken place, for it can be paralleled by the depressions we are able to demonstrate.

If these elevations have occurred, we can at once account for the presence of those shallow arms of the sea that separate us from the Continent. They must have been cut by the shore-waves during the gradual rising of the land, and the *débris* flung over the deeper parts of the ocean. They are very shallow. The deepest point of the strait between Folkestone and Calais is about 150 feet; an elevation to half that extent would again bring a large proportion of the surface within the erosive powers of the sea-waves. Its shallowness may be imagined from the fact that on a profile section of the Strait of Dover 65 feet in length this extreme depth would be represented by a depression of only one inch.

On a comparison of the geological maps of the opposite coasts of England and France, the suspicion that these water-filled depressions which divide them are the result of erosion becomes greatly strengthened. The long oval of the wealden formation that stretches through Sussex into Hants, and is cut through by the coast of the English Channel, is seen to be continued and completed on the opposite coast of France. The "basset" or out-cropping edges of the chalk which form the North and South Downs of England find their continuation precisely opposite, and in the same general relations on the French shores. Outside them, precisely as in England, lie the tertiaries. The two countries have clearly been carved out of a single geological block. The waters that now form the English Channel flow in a very shallow groove, worn on the upper face of this block, the strata of which it is composed being continuous under the shallow waters.

The grand idea which this conception gives us of the power of the sea during long-continued periods of time dwindles into nothingness beside the tremendous amount of erosion that the ocean has effected around the British Islands. A study of the soundings around the coasts of these islands shows that they stand upon an elevated platform connected with the continent of Europe, with a submerged surface everywhere less than 200 feet below the present level of the sea. Outside the line of 220 feet, the water deepens rapidly to a depth of several thousands of feet. These deep waters thus surround a giant sea-terrace, stretching out from the shores of Europe into the Atlantic Ocean. Out of the waters which now bathe this terrace rises the swarm of islands and islets of Great Britain—like the reefs and skerries that jut through the waves on a coast-platform at highest tide. It has all the appearance of an old peninsula, which, like that of Spain and Portugal of the present day, once formed an integral part of the European Continent. The waves of the wild Atlantic working ceaselessly for untold æons, aided by many an elevation and depression, have shorn it into a sloping ocean platform, out of whose covering waters rise the worn and wasted fragments that form our beloved island home.

If we started our quest with the impression that the land was the type of stability, we can no longer hold this opinion. We find now that, within its limits, the land is as changeable in its behaviour as the sea itself, and as much a creature of moods — now lifted, now depressed, now exposed to the balmy air of heaven and draped with its garment of green, now forming part of that mysterious sea-floor of which science has so much, and yet so little, to tell! The word "change" is writ large in the book of Nature's workings.

WHAT IS RADIUM?

By WILLIAM ACKROYD, F.I.C.

WHAT is radium? This is the question which everyone has been asking of late. The name is not a new one, as scientific men have been familiar with it for three or four years, and a chemist would reply that radium is an element, one out of seventy-eight simple substances of which the universe is composed. The extraordinary qualities of the radium compounds are due to the radium in them, but up to now the metal itself has not been isolated on account of its extreme rarity, which is also responsible in the main for the present market price of its compounds—£180,000 per pound avoirdupois! It is sold by the grain or the milligram; gold is as dross compared with it, and even diamonds are cheap in comparison.

From recent experiments it has appeared as if radium compounds were a never-failing source of heat. Thus *barium chloride*, containing a small amount of *radium chloride*, was found to maintain a temperature of 1·5° C. above that of the surrounding atmosphere, and appeared to do it continuously, as if it had in itself undying fire. Nothing more anomalous could have been encountered by investigators who are disbelievers in perpetual motion of any kind—even of the molecules of radium compounds—unless there is some external source of energy supplying the necessary force. We are, indeed, all believers in the old Latin observation, "*Ex nihilo nihil fit*"—familiarly rendered, "You cannot get something out of nothing"—and we may rest assured that it applies to all natural phenomena.

It is in the search for this element with such out-of-the-way qualities that M. Pierre Curie, professor at the École de Physique et de Chemie Industrielles, Paris, has untiringly given his time, from the days in 1898 when its existence was barely suspected up to 1903, when everyone acknowledges its place among the known elements.

To commence our account of radium compounds and their wonders at the very beginning, we have to state that the element radium has an *atomic weight* of 225—in other words, its ultimate indivisible particle is 225 times heavier than a similar particle of the element hydrogen, whose atomic weight is practically regarded as 1. Mme. Curie has recently obtained this number 225; but still more recently the two German observers Runge and Precht give spectroscopic reasons for supposing the atomic weight to be probably 258.

In the early history of an element differences of opinion of this kind usually occur, and they detract nothing from the importance of the labours of the various investigators, who have all to wait for the final evidence which will settle the point one way or the other. An atomic weight, however, is always necessary to definitely fix the position of the new element among its fellows, and if the number 258 be finally adopted it will place radium far outside all other elements. It must also be the rarest in the universe, for, as I attempted to show at the last meeting of the British Association for the Advancement of Science, at Belfast, in the distribution of the elements the very rarest have the highest atomic weights, and it would be reasonable in the present instance to suppose that the element radium, with an atomic weight higher than all others, would be scarcer in

Series.		Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.
1	—	Hydrogen... 1	—	—	—	—	—	—	—
2	Helium .. 4	Lithium ... 7	Beryllium 9	Boron 11	Carbon ... 12	Nitrogen... 14	Oxygen ... 16	Fluorine ... 19	
3	Neon..... 20	Sodium..... 23	Magnesium 24	Aluminium 27	Silicon..... 28	Phosphorus 31	Sulphur ... 32	Chlorine .. 35.5	
4	Argon ...39.6	Potassium 39	Calcium ... 40	Scandium... 44	Titanium... 48	Vanadium 51	Chromium 52	Manganese 55	Iron .... 56 Nickel .... 58 Cobalt 59
5	—	Copper...... 63	Zinc........ 65	Gallium .. 70	—	Arsenic ... 75	Selenium 79	Bromine ... 80	
6	Krupton. 81.6	Rubidium... 85	Strontium 87.5	Yttrium ... 89	Zirconium 90	Niobium ... 94	Molybdenum 96	—	Rhodium... 104 Ruthenium 104 Palladium 107
7	—	Silver 108	Cadmium 112	Indium ... 114	Tin 118	Antimony 120	Tellurium 125	Iodine 127	—
8	Xenon ... 127	Cæsium ...133	Barium ... 137	Lanthanum 139	Cerium ... 141	Didymium 145	—	Samarium 150	—
9	—	—	—	—	—	—	—	—	
10	—	—	—	Ytterbium 173	—	Tantalum 183	Tungsten... 184	—	Osmium ... 191 Iridium ... 193 Platinum... 195
11	—	Gold 197	Mercury ... 200	Thallium... 204	Lead 207	Bismuth ... 208	Norwegium 214	—	—
12	—	—	Radium ... 225	—	Thorium... 233	—	Uranium... 240	—	—
13	—	—	Radium ... 258	—	—	—	—	—	—

FIG. 1.—CHART SHOWING THE PLACE OF RADIUM IN THE PERIODIC CLASSIFICATION OF THE ELEMENTS.
(Newlands and Mendeleeff.)

nature than all others. The price quoted is sufficient commercial confirmation of the fact.

The place of radium among elements can only be intelligently grasped by a survey of them from the standpoint of the periodic classification, which is exhibited here in its simplest form in the accompanying table (Fig. 1).—

Here, as will be seen, the elements are arranged in the order of their atomic weights in horizontal lines or series from 1 up to 12, and fall into vertical groups from I. to VIII., with an added group for the recently discovered elements of the atmosphere—*helium, neon, argon, krupton,* and *xenon.* Radium finds its place at the bottom of Group II., and with an atomic weight of 225 its position would make it form a symmetrical horizontal series with *thorium* and *uranium*—metals possessing some similar properties, although to a much less degree. If, however, the atomic weight be taken as 258, then radium has a place all to itself, forming the only element in a thirteenth series, and indicating the possibility of existence of other elements which are at present unknown to chemists, unless they be *actinium* and *polonium,* elements which exhibit properties like radium, although to a lesser degree, and are so extremely rare that as yet chemists have not been able to prepare compounds of them, while some even doubt their existence.

Now, in one of these vertical groups, after leaving the second series, all elements in alternate squares exhibit family relationships—that is, if we consider some particular property which they all

possess in common, it will gradually increase or decrease as the atomic weight increases. It also shows itself in the similarity of manner in which their compounds are built.

The metals with which radium is comparable—or, in other words, those belonging to the same family—are *calcium*, *strontium*, and *barium*, and as the end member of the group it has extreme properties. The points of relationship are seen in the similarity of the compounds they form with other elements; thus picture representations of the chlorides and bromides of barium and radium would be as shown in Fig. 2.

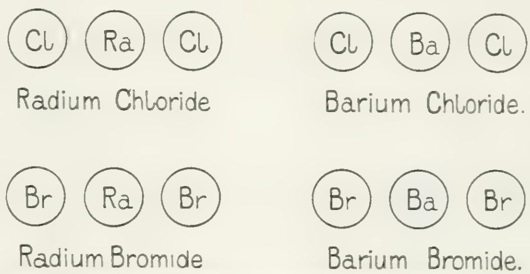

FIG. 2.—GRAPHIC REPRESENTATION OF ATOMS IN THE MOLECULE.

Each of these circles is supposed to represent an atom, and the molecules of radium chloride and bromide represent ternary atomic systems, which from the pictures will be seen to have relationship in similarity of build to the barium compounds. Nay, we even suppose that their molecules are similarly shaped in space, because the substances are *isomorphous*—that is to say, the molecules are built in aggregates which give the same form of crystals.

Another remarkable point of family likeness is in their exhibition of the phenomenon of phosphorescence under divers conditions. Phosphorescence is the emission of a faint light in the dark. The cause may be mechanical, as when two pieces of loaf sugar are struck together in a dark room. It is also brought about in some substances by light and heat. Compounds of the calcium family of elements give remarkable manifestations of it. Calcium fluoride or Derbyshire spar gives out a faint light when heated in the dark; calcium sulphide, known to everybody twenty years ago as *Balmain's paint*, gives out light in the dark after the light of the sun has fallen on it; sulphide of strontium will exhibit phosphorescence even after exposure to diffused daylight; barium sulphide, sometimes called *solar phosphorus*, behaves similarly after solar exposure; and *barium platino-cyanide* makes the most efficient of phosphorescent screens when it is brought under the influence of X-rays.*

Now, in comparing such elements we look not for identical properties, but for gradual increase or gradual decrease of a given quality with increase of the atomic weight. In the present instance it appears that so far as their relations to radiations, visible and invisible, are concerned, their powers of emission increase with atomic weight, and many of the remarkable manifestations of radium compounds are possessed in extreme degree in virtue of this element, being the end member of its group. Let us in this connection examine one of these qualities—that of *radio-activity*, for which radium compounds are so noted.

When an electroscope (Fig. 3) has been charged with electricity its self-repelled leaves remain apart for some time (Fig. 4); but if a substance like the mineral pitch-blende, containing radium, be brought into position over it the leaves fall quickly together (Fig. 5); some influence has emanated from the pitch-blende to produce this

* CASSELL'S POPULAR SCIENCE, Vol. I., p. 83.

effect, and this peculiar power is termed *radio-activity*. It is the same quality of "radio-activity" which makes a radium compound produce photographic effects, or render luminous screens of barium platino-cyanide and zinc sulphide, which are used as tests for X-rays. In a word, radio-active bodies appear to give rise to X-rays without the aid of all the complications of battery, condenser, and focus-tube. The substances possessing these qualities most prominently are compounds of *thorium*, *uranium*, and *radium*. *Thorium* and *uranium* are names which are, no doubt, already familiar to the reader. Thorium in the form of oxide is the principal constituent of the Welsbach mantle*; uranium compound is the cause of the greenish yellow fluorescent light which is exhibited by certain kinds of ornamental glass. The radio-activity, however, of compounds of both are weak compared with the power possessed by those of radium, which is 100,000 times more active than uranium.

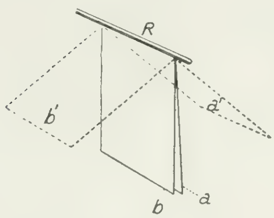

FIG. 3.—DIAGRAMMATIC REPRESENTATION OF "LEAVES" OF ELECTROSCOPE.

a b, uncharged.
a' b', charged with electricity.

These emanations have been termed Becquerel rays, after the French physicist M. Henri Becquerel, to whose early labours we owe much of our knowledge concerning them. They are said to be intermediate in their properties between ordinary light and X-rays. Thus, to take the familiar experience of skin blistering, the sun's rays will, under suitable conditions, make the skin peel off the nose and face, and produce sunburn; X-rays will do something more, as careless or ignorant operators have found to their cost, for they will positively injure the skin and produce slowly healing sores, and even make the nails come off. Becquerel rays, as exhibited by uranium, are intermediate in their effect, although it would now appear from recent experiences that it is more or less a question of quantity, as radium compounds with their torrents of Becquerel rays produce effects which are quite comparable, for extent of damage to the skin, with those produced by X-rays. It is, indeed, dangerous to carry even the smallest amount of radiferous material in the pockets; as in the course of a few hours signs of its action begin to be apparent in gradually increasing redness of skin, ending in sores, which require dressing and take a long time to heal.

There are, besides, active emanations of another character than the Becquerel rays. This will be clearly perceived while considering some of the remarkable effects

FIG. 4.—ELECTROSCOPE CHARGED.

In this type of electroscope only one "leaf" is movable, the other being fixed to a plate of brass of the same shape.

which Sir William Crookes has observed with the compound known as *radium nitrate*. A solution of the salt evaporated to dryness exhibited a faint luminosity in the dark which made screens of barium platino-cyanide and zinc-blende glow with their characteristic light. A

* *See* Fig. 5, Vol. I., p. 278, CASSELL'S POPULAR SCIENCE.

diamond crystal glowed with a pale bluish green light. This observation is particularly interesting as illustrating one of the

FIG. 5.—ELECTROSCOPE DISCHARGED BY THE AGENCY OF A RADIO-ACTIVE SUBSTANCE SUCH AS PITCHBLENDE.

points of likeness between Becquerel rays and the rays in the focus tube. Many years ago Crookes mounted a diamond in the centre of an exhausted bulb, and subjected it to a negative discharge of electricity, in the way X-rays are now produced; the diamond shone with a bright green light, very much as it now can be made to glow in the invisible rays from a radium compound (Fig. 8). A similarity thus appears to be demonstrated between the two kinds of emanations. Further curious effects were observed. The screen of zinc-blende, having been touched with particles of the nitrate of imperceptible smallness, had its surface dotted with brilliant specks of green light, some a twenty-fifth of an inch across or more, although the specks of radium compound producing the effect were too small to be seen in daylight. One of these centres of illumination, when examined in the dark under a low power of the microscope, was dull in the middle part, which was surrounded by a luminous halo. The dark centre itself appeared to shoot out light at intervals in different directions, and outside the halo the surface of the screen scintillated with sparks of light. No two flashes succeeded one another on the same spot, but they were scattered over the surface, coming and going instantaneously. A solid piece of radium nitrate, brought gradually near the screen and then taken away, produced these various phenomena, which could be seen most markedly when the nitrate was about half an inch off, but disappeared when the distance had increased to two inches and more. The emanations were prevented from reaching the blende when a card was interposed between the nitrate and the screen, which Sir William attributes to the electrical character of the particles being attracted or arrested by the coarser atoms or molecules of the screen. In a word, he regards these infinitely small particles which emanate from the radium compound as being the electrician's atoms or *electrons*, thousands of which are supposed to exist in and around the chemist's atoms (Fig. 6). It will possibly admit of a less remote explanation, but it is certainly fascinating to regard the phenomenon of scintillations presented by the zinc-blende screen as being due to a bombardment of electrons from the nitrate hurled off with the speed of light, the impact of each electron being rendered apparent only by the enormous

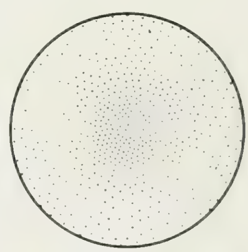

FIG. 6.—"ELECTRONS" IN AN ATOM.

An atom was until recently supposed to be the smallest particle of an element. Now some believe it to contain hundreds of "electrons," which are in a state of constant activity.

extent of ether disturbance it produces. The alternative explanation would be that minute sub-microscopical particles were hurled off from the radium compound—in other words, that the nitrate suffers slight decrepitation.

But how shall we explain the fact of radium compounds keeping a temperature of one or more degrees centigrade above that of the surrounding atmosphere, and of evolving more heat than an equivalent weight of burning hydrogen? We are here, indeed, in face of a mystery. It is probably due to a combination of causes. One is, absorption of radiant energy from without, which is transformed into heat, and may, under certain regenerative conditions, be increased. Another, suggested by Sir William Crookes, is that the atomic structure of radio-active bodies is such as to enable them to absorb energy from the moving molecules of air. These molecules travel about with different speeds, and it is suggested that the most quickly moving among them have their motion arrested by having it taken up by the radium compound. In this way the radiferous body is kept a centre for emission of the energy it has received, and it continuously sends it out in another form, converting mechanical motion into heat and radiant emanations.

There remains here, however, an unexplained peculiarity. X-rays and Becquerel rays, as we have seen, are practically the same as judged from their effects. Sir G. B. Stokes showed some years ago that the peculiar characteristics of X-rays are probably the result of their pulsating character—the rhythmical series of ether-puffs, so to speak, caused by the contact-breaker of the large induction coil.* If Becquerel rays have this pulsating character, how is it acquired? To this question there has been hitherto no answer. I have made a suggestion as to the possible cause, which involves a slight excursion into another domain of science—*radiophony*. In 1880 Professor Graham Bell discovered that many different substances emit sound when exposed to the action of a rapidly interrupted beam of sunlight. This interesting observation is made clear by reference to Fig. 7. The sun's light was reflected from a *heliostat* M, and converged by the achromatic lens *l* on to the slits of a revolving disc *a b*, seen in plan *a′ b′*. The passage of the light forward was thus rapidly interrupted, and the pulsating beam was then converged by means of the lenses *l′* and *l″* on to a test-tube holding the substance to be experimented on. Wooden chips in the test-tube emitted a clear musical sound.

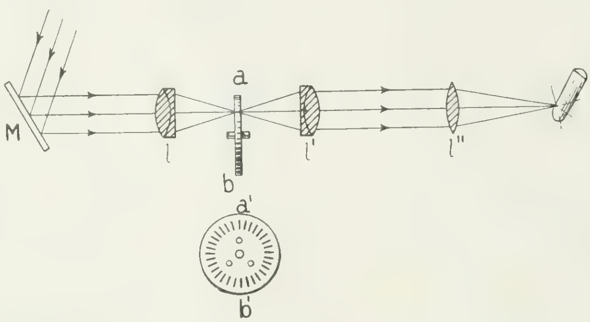

FIG. 7.—A DISC INTERRUPTER MAKING CHIPS OF WOOD HUM.
M, heliostat; l, achromatic lens; a b, revolving lens; a′ b′, the same in plan; l′ l″, the lenses.

One of the remarkable features of modern science is the utilisation of the principle of reversibility. The reversibility of the events concerned in the turning of a dynamo gave us the electro-motor, and the possibility of the reversal of a chemical reaction is a never-ending source of research to the chemist. In the phenomenon under consideration a pulsating beam of light gives molecular vibration to a non-metallic substance which in turn generates atmospheric molecular motion audible as sound. A reversal of

* *See* Fig. 5, CASSELL'S POPULAR SCIENCE, Vol. I., p. 75

this would be the transfer of atmospheric molecular vibration (and it is immaterial whether it is evident as sound or not) to a non-metallic body like a radium compound, whose molecules are so weighted as to favourably receive the characteristic motion which is required to confer on its ethereal radiations a pulsating character. This supplemental illustration of a possible and highly probable reversible operation makes clearer the manner in which atmospheric molecular motion may be transferred to radium compounds, and helps to explain the origin of pulsating ether undulations from them.

Such is a brief account of what we know concerning radium. Nowadays a new element may be discovered without anyone being much put about; radium has proved an exception. It has been a real cause of excitement to philosophers, as it appeared at one time not improbable that some old laws were going to be broken. Things have quieted down again, and one may now predict that all the wondrous new facts which have been obtained will prove nothing more and nothing less than that radium is entitled to its position as possessing the heaviest weighted atom of any element in the universe.

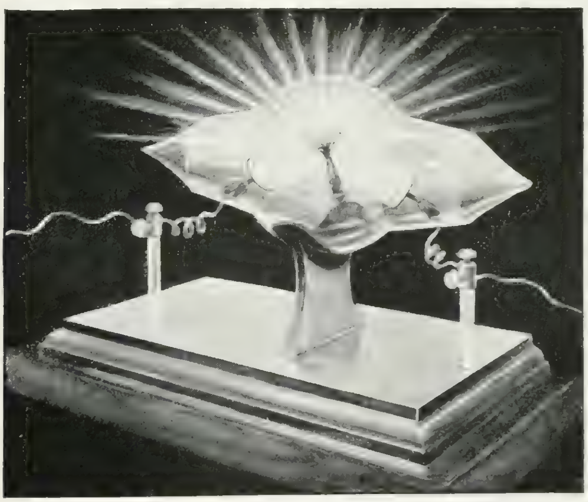

FIG. 8.—A PHOSPHORESCENT DIAMOND.

In this experiment the diamond is made phosphorescent by the negative discharge (cathode rays) directed upon it.

THE SOUNDS WE HEAR.

By T. C. HEPWORTH.

THE faculty which we possess of hearing and appreciating different sounds is one of our most valued senses. From our earliest childhood we educate ourselves far more by means of this sense than by any other. It is a well-known fact, and one which should teach us how much we owe to our ears, that the deaf and dumb are silent not from any malformation of the organs of speech, but because they lack the sense of hearing. Not only is sound our principal means of intercommunication, but in many other ways it ministers to our wants and to our pleasures. Whether we instance the lowing of cattle, the hum of insects, the song of birds, and the innumerable other pleasant sounds which add to the enjoyment of rural scenes, or the methodical arrangement of tones which we call "music," and which forms a language which all can understand, we must confess that through our ears we receive much benefit as well as pleasure. It behoves us, therefore, to learn something of the nature of sound, and of the natural laws upon which it is dependent.

We can none of us fail to be aware that sound takes a certain time to travel from the source of its production to our ears. The distant gun will show its flash and puff of smoke long before its dull boom is made evident to our sense of hearing. The workman's hammer will seem to fall silently upon his work, for the sound does not reach us perhaps until it is uplifted for the next stroke. The thunderclap, though it is really concurrent with the dazzling flash that seems to precede it, often by many seconds, is a still more common illustration of the same phenomenon. But perhaps the most striking instance of this property of sound may be observed when a long file of soldiers is on the march, preceded by a band of music. The men farthest from the band will be quite out of step with those in front, although each man of the company will place his foot to the ground in time with the music *as it reaches his ears*. It is probable that the only men who correctly keep time are the musicians themselves, for they alone can hear the sounds at the exact moment of production.

In 1822 a French commission was appointed to make certain experiments with a view to obtain definite information as to the velocity of sound in air. Two hills, near Paris, were chosen as the theatre of operations, a cannon being placed at each station. By noting the time which elapsed between the flash of the gun and the arrival of the report, and knowing the distance which the sound had to traverse, these experimenters were able to fix its velocity at 1,118 feet per second for the temperature which happened to prevail at the time. The mean velocity of sound in air is generally stated as being 1,125 feet per second.

Sound has been defined as "vibration appreciable by the ear." Some bodies are more sonorous than others—that is, by reason of their hardness or elasticity they will more readily vibrate. An ordinary glass tumbler will, if placed upside down on a table and struck with the finger-nail, emit but a feeble sound; but if it be held above the table, so that its sides may be free to vibrate, it will give out a clear, bell-like tone. Such vibrations are communicated to the particles of air in the neighbourhood of the sounding body:

these give them up to other particles, until in the form of sound-waves they strike upon our ears. These waves of sound have been compared to the ripples caused by a pebble thrown into still water, for they spread in the same manner from the centre of their production. They may be more properly likened to the beautiful undulating waves which appear to pass over a field of standing corn when agitated by the wind. We well know that the several ears of corn do not really travel onward, but they each have a certain limited movement to and fro, which helps forward the progress of the wave. In the same manner the individual particles of air push onward the sound-waves, although their own movement is but of small extent.

The older philosophers were unanimous in supposing that air was the only medium through which sound could travel, and not until the middle of the eighteenth century was this theory disputed. But we now know that all bodies, whether solid, liquid, or gaseous, are capable of conveying sound to our ears. It is also certain that the presence of some such body is absolutely necessary for the purpose. This last fact is made evident by an experiment which is an old favourite with lecturers upon acoustics. A bell, having a clockwork or electric attachment which causes it to ring automatically, is placed under the receiver of an air-pump (Fig. 1). As the air is gradually exhausted the sound becomes fainter and fainter, until at last it ceases altogether, although it can be seen that the hammer is striking the bell as vigorously as ever. As the air is re-admitted the sound is gradually restored. Mountaineers find that it is necessary, when at any great height above the sea-level, to speak with great effort, otherwise their voices are unheard. A pistol-shot under the same conditions appears to be little louder than the crack of a whip, the natural rarefaction of the air at such altitudes placing the operators in the same position as the bell under a partially exhausted air-pump receiver. In order to make this experiment successful, it is necessary to place the bell upon a cushion of wool or some other soft material, otherwise the vibrations would be communicated to the framework of the air-pump, and so to the external air. We learn, therefore, from this experiment, first, that sound in a vacuum is sound no longer; and, secondly, that solids are capable of transmitting sound.

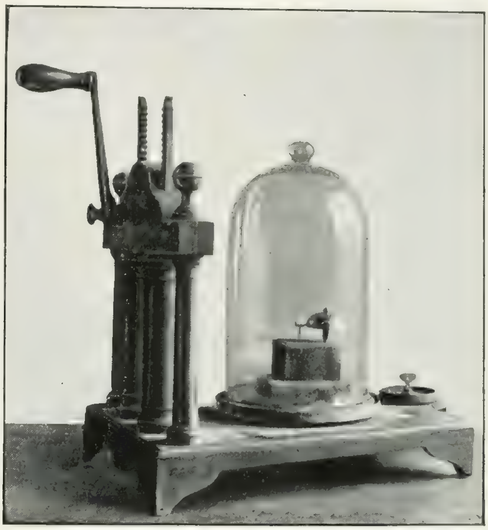

FIG. 1.—BELL UNDER AIR PUMP.

"As the air is exhausted the sound of the bell becomes fainter and fainter, until . . . it ceases altogether."

There are various atmospheric causes which contribute to obstruct the waves of sound. It is within the experience of everybody that a distant bell is sometimes heard very plainly, and at other times is quite inaudible, according to the direction of the wind. But fog, rain, and snow also interfere with sound-waves, and more or less stop their progress. In clear, cold weather, sounds are much better heard than in summer, when the rising heat

from the earth's surface induces currents of air which interfere with their transmission. In the Arctic regions—during the coldest season of the year—it is said to be possible to carry on a conversation with a person at more than a mile distant, the air being there of a uniform temperature and density. For the same reason, sounds which in the daytime would be unnoticed, strike upon the ear at night with startling distinctness. But, of course, the general silence at that time must be taken into consideration.

In order to show that sound vibrations can be sent through water as well as through air, the simple experiment indicated in Fig. 2 may be tried. A tuning-fork fixed in a block of wood is smartly struck, but it will give out but a feeble sound until the block is immersed in the glass of water, the liquid taking up the vibrations, while the sound is intensified by the hollow box or resonator upon which the vessel stands. The velocity with which sound travels through water was demonstrated in a very practical way some years ago.

Observers were placed in two boats, which were moored at a certain distance apart on the Lake of Geneva. One boat was furnished with an apparatus by which a submerged bell was struck at the same instant that a charge of gunpowder was ignited in the air above it. In the other boat an ear-trumpet was used to detect the arrival of the sound through the water, the lapse of time between the noise and the flash being noted by a chronometer. By this means it was ascertained that sound travels in water at the rate of 4,708 feet per second, being about four times the rate of progress in air. It must be understood that the velocity of sound in water, as in air, is subject to variation by temperature—the higher the temperature the greater the velocity.

The travelling powers of sound through solid substances may be stated generally to be far more rapid than through either air or water. The metals, on account of their elasticity, naturally stand at the head of the list. The first trustworthy experiments in this direction were made by the French philosopher Biot, by means of the empty iron water-pipes of Paris. He caused one end of a pipe a mile long to be struck with a hammer. At the other end he found that two distinct sounds became audible, the first being conveyed to the ear through the metal of which the pipe was composed, and the later sound by the air contained within the pipe. It was thus proved that cast-iron will convey sound at the rate of 16,822 feet per second, or about fifteen times more quickly than air. The phenomenon of the double sound is also

FIG. 2.—VIBRATIONS SENT THROUGH WATER.

A tuning fork fixed in a small block of wood is smartly struck and then immersed in water.

heard during blasting operations, provided that the observer is at sufficient distance from the place of explosion. The first sound is conveyed through the substance of the earth, and the other

through the air. This conducting power of the earth is taken advantage of by savages, whose practised ears placed in contact with the ground can detect the approach of a horseman long before he is visible.

The transmission of sound through wood can be easily demonstrated by placing the ear at the extremity of a wooden rod, while an assistant gently scratches the other end with a pin. Although the sound may be far too faint to be detected through the intervening air, when heard by means of the rod it is surprisingly distinct. An experiment, showing the wonderful conducting power of wood, was shown some years ago in London, under the name of the "Telephonic Concert." It took place in a large building, consisting of three different floors. In the basement were placed four performers, who constituted a small orchestra. Attached to the instruments which they played were wooden rods, about half an inch in diameter—one rod for each instrument. These rods passed through the ceiling of the room in which the performers were seated, and through the intermediate apartment to the top floor of the building, where the audience were assembled. In this room the four rods were connected with the sound-boards of four harps, and the music was most plainly heard by everyone present, although it was quite inaudible in the room through which the rods passed. This experiment can also be carried out by means of two pianos similarly connected. We may also produce the same effect upon a small scale by means of a musical box. Let it be placed, wrapped in felt, in any box or cupboard, so that its sound may be completely smothered. If, through a small hole, a rod of wood be connected with it, and the other end of this rod be placed against a box, or violin, the sound will be immediately rendered audible.

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It will be observed that the sound in both these cases, and also in the experiment illustrated in Fig. 2, is helped out by the addition of a sounding-board, or box. And this fact is of extreme importance in showing us how much musical instruments—and stringed instruments in particular—depend for their effectiveness upon the association of some such resounding body. Thus, in the violin or guitar we have a hollow box, the strings of a harp are fastened to a similar box, and the wires of a piano are stretched over a board which, looking to the manner in which it is held by the framework, really constitutes the bottom of a shallow box. If we suspend from our finger a violin string and attach to it a heavy weight, so as to give it the same tension that it would have when strung on the instrument, we shall find that the sound it will give is merely a dull thrill, very unlike the pure, ringing tone that it possesses when mounted on its proper resonant case. The same effects are observed in the use of the ordinary tuning-fork. When made to vibrate by means of a blow, no sound is heard unless the fork is held close to the ear. But if its foot be held against a table-top or any similar body, its note immediately swells out, so that it can be heard at a distance of several yards. These augmented sounds are due not to the strings or tuning-fork, but to the vibrations communicated by them, and taken up by the resonant board or box against which they are placed.

Sounds can also be greatly reinforced by the near presence of resonant cavities. A convenient mode of proving this is by means of two ordinary glass tumblers. One of the glasses is placed upon a table and is caused to vibrate by a sharp tap from the finger-nail. The other tumbler is then brought near its edge, as shown in Fig. 3, when the sound will at once be almost doubled in intensity. By moving

the second tumbler to and fro, the sound is caused to swell out in a curious manner every time the stationary glass is passed over. In nature, the noise of a waterfall is often much increased by the near neighbourhood of a cavern or hollow in the rocks. And we have a still more familiar instance of the same phenomenon in "the murmur of the sea" which children suppose that they hear when holding a hollow shell to their ears. The many unnoticed sounds always present in the air are here augmented by the resonant cavity of the shell.

FIG. 3.—SOUNDS REINFORCED BY THE PRESENCE OF A RESONANT CAVITY.

And now a word about *echoes*. According to the old mythological story, Echo was a nymph who had displeased Jupiter by her extreme talkativeness, and more especially by her repetition of certain little matters not altogether creditable to him. She was therefore deprived of speech, but was still allowed to answer any question that might be addressed to her. She afterwards became the victim of unrequited love, "fell into a decline,' and was eventually transformed into a stone which retained the same conditional power of speech. Such is the fable in which the ancients wrapped up the ordinary phenomenon which we still call an "echo," but which science explains in a far more prosaic manner.

As an indiarubber ball bounds back from any surface against which it is propelled, so are sound-waves intercepted by any obstructing surface and cast back to the place of their production. This return of the sound-waves constitutes an echo. A certain distance between the source of the sound and the surface which reflects it is necessary for an echo to become perceptible. The reason of this is that the sound requires time to travel from its source and back again; and unless there is sufficient distance for this to happen, the echo is merged into the original sound and is confounded with it, the result being merely a reverberation. In cathedrals and large buildings where the pillars and walls form many obstructing surfaces, the waves reflected from them cause that confused ringing noise observable not only when a person speaks, but also when a chair is moved or a door slammed. The smallest distance at which an echo of one syllable can be heard is about 140 feet. Sound travels at the rate of 1,125 feet per second. In a fourth part of this time it would go over a space of 280 feet, or 140 feet in one direction and 140 feet back again. Less time than this quarter of a second would not allow for the articulation of even one syllable; but if the distance of the reflecting surface were doubled, two syllables could be uttered; if trebled, three, and so on. Some places are famous for echoes which will repeat themselves again and again. This is owing to the number of different surfaces which happen to be so placed as to reflect the sound-waves to one common point.

It is very interesting to note that the reflection of sound is subject to the same laws which govern the reflection of both light and heat. Indeed, the concave reflectors shown in Fig. 4 may be used to demonstrate the phenomena connected with either one or the other. We will suppose that the mirrors are placed about

thirty feet apart, exactly facing each other. If a bright light be placed at the point marked *a*, which is the focus of the left-hand mirror, its rays will be reflected to the other mirror, and concentrated at the point *a′*. If, instead of the light, a watch be hung at *a*, its ticking will be plainly heard if the ear be placed at *a′*, although it will be quite inaudible at any other point. Again, if a brazier of live coals be placed at one focus, a combustible substance at the corresponding point of the other mirror will be ignited. We see here one of numerous examples of the manner in which the forces of nature act in harmony with one another. A sentence whispered to the focus of one reflector is heard at the other, but is inaudible to anybody passing between them. In whispering galleries, such as that in St. Paul's Cathedral, the sound is reflected by the curved wall from point to point, until it reaches the listener's ear.

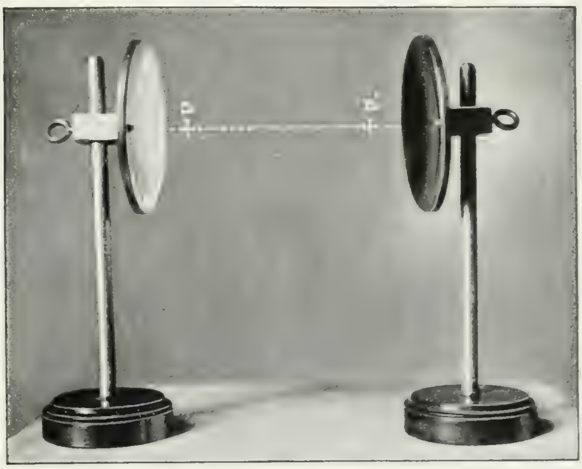

FIG. 4.—EXPERIMENT SHOWING THAT HEAT AND LIGHT OBEY THE SAME LAWS AS SOUND.

a á, foci of the reflectors.

The speaking-trumpet is an instrument which is dependent for its power both upon the reflections of the speaker's voice from its sides, and the concentration of the sound due to its tubular form. The ear-trumpet used by deaf persons is but a modification of it. A fog-horn, much the same in construction, is used on many parts of our coasts as a warning to mariners when the weather is too thick for beacons to be visible. This horn is an immense trumpet-shaped tube, furnished at its mouth with a metallic reed. An air-pump, worked by steam power, supplies a strong current of wind, which sets the reed in vibration. The piercing scream from one of these horns can be heard over the sea for many miles. The megaphone (Fig. 5) is merely an adaptation of the speaking-trumpet.

The action of speaking-tubes, which are now so common in offices where the employés are separated by different floors, is not difficult to understand. The movement of sound-waves has been already compared to the widening rings which are caused when a pebble is thrown into still water. In the speaking-tube these rings, instead of being left to die away into silence, are preserved with all their first intensity until they reach the utmost limit of the tube which confines them.

We will now pass on to the consideration of musical sounds. The line of demarcation which separates mere noise from music is rather difficult to determine. If a door be slammed, the sound reaches our ears as an unpleasant jarring of the nerves, and we call it "noise." If a bird rises near us we hear the flutter of its wings as a series of flaps in quick succession, approaching, in some degree, a continuous thrilling sound—but still, it is only noise. In the wing of the bee and other insects we have exactly the same vibratory motion, but with a different result, for we here obtain a distinct

note, the musical value of which we can appreciate and determine. Let us pause for a moment and consider in what this vibration consists. The moving pendulum of a clock will perhaps give us the most homely example of a vibrating body. We find that it oscillates on each side of a place of natural rest, and that the rate or velocity of these oscillations is proportionate to its length. Or, to put it more clearly, we know that if the clock is too slow, we can quicken its movement by slightly raising the weight which is attached to the pendulum, and that, if it is too fast, the contrary action will immediately retard it. By such means we practically shorten or lengthen the pendulum, as the case may be. But, whatever be its length, it oscillates without any apparent sound. Of course, we cannot here consider the "tick," which is caused by the mechanism of the clock. Let us see whether we cannot find means to obtain a sound from this pendulum, or from a piece of metal nearly approaching it in size and substance. The elastic blade of a fencing-foil will answer the purpose as well as anything else that we can hit upon. We will suppose that this blade or rod of steel is about four feet long, that its lower end is fixed firmly in a vice, and that the other end is free. On pulling the free end aside, and suddenly letting it go, the rod is thrown into vibration, and a low fluttering sound is emitted from it, which gradually fades away until the rod is again at rest. We will shorten the rod by placing more of it into the vice; when we now cause it to vibrate, a musical note is the result; but the pitch of the note obtained is very low. By shortening the bar still further we obtain a higher note, and by adjusting it to different lengths in this manner we shall find that we can obtain from it every note of the scale.

Photo: W. J. Campbell, Creed Lane, E.C.

FIG. 5.—A MEGAPHONE.

This is a familiar object at regattas and upon shipboard. Its hoarse "voice" is not musical, but it carries far.

Now, we have already seen that by reducing the length of a pendulum the rapidity of its oscillations is increased. Exactly the same law holds good in the case of the fixed rod, so that we may guess that the pitch of a musical note is in some way dependent upon the velocity of the vibrations to which it owes its origin. We just now noticed that a bird's wing will not emit anything but

a succession of beats, while the same motion in the wing of a bee will produce a musical hum. Now, the wing of the bird is, in fact, a counterpart of the vibrating rod as we first placed it in the vice. It merely flutters. But shortened, as in the case of the insect, it is capable, by its quicker vibration, of yielding a musical impression. A musical sound, therefore, requires not only that the vibrations which produce it must be strictly periodic in their occurrence, but that they must follow one another in quick succession. Experiment has shown that the least number of vibrations per second which will give an appreciable musical sound is sixteen, so that we may approximately say that any less number will produce only noise, the pulsations being too disconnected to give anything more than simple percussions. From this lowest sound of sixteen vibrations we can gradually rise by innumerable steps to extremely acute notes which give upwards of 30,000 vibrations per second, but the highest musical sound of any practical value will give in every second of time about 4,000 vibrations.

It would seem almost beyond the bounds of possibility for any substance to execute a movement to and fro four thousand times in the very small period represented by one second. Yet it is not difficult to show that this is an absolute fact, and that it is capable of proof. A series of knocks or taps—provided that they follow one another with sufficient rapidity—will produce a musical note. A card held against a revolving toothed wheel is one mode of demonstrating this. It is evident that if such a wheel be furnished with a counter to record its revolutions (in the same manner in which the turnstiles at public exhibitions are made to check the number of persons passing through them), the sum of such revolutions per second, multiplied by the number of teeth upon the wheel, will give the number of taps or vibrations requisite to produce a note of any definite pitch. If one blade of a vibrating tuning-fork be made to touch a sheet of paper, the consecutive blows thus given to the paper will resolve themselves into a musical note, which, of course, will be the same note as that given by the fork itself.

It is easy to show that the prongs of a struck tuning-fork are in active vibration,

FIG. 6.—SHOWING THAT THE PRONGS OF A TUNING FORK ARE IN ACTIVE VIBRATION AFTER A BLOW.

If the suspended ball is allowed to touch the point of one of the prongs it is propelled several inches away.

and that they are capable of exerting a certain amount of energy. In Fig. 6 a tuning-fork is inserted in a hole in a box, and, after being struck, a pith ball at the end of a silken thread is brought against one of the prongs. The ball is immediately propelled some inches away from the fork, provided that the little ball be applied at the end of the prongs. It will be found that as the ball is brought into contact with the fork lower down the action becomes less, until when the base of the prongs is reached little or no effect is observed.

Travellers by railway have very often before them an example of the dependence of the pitch of a note upon the rapidity with which the vibrations are transmitted to the ear. When a passing engine is sounding its whistle, the pitch of the note sounded appears to rise considerably at the moment of approach, and sinks below its former pitch directly it has passed. The succession of sound-waves is here artificially quickened, and then retarded, by the rate at which the engine itself is moving to, and afterwards from, the observer. In the same way a vigorous swimmer will, on receding from the shore, meet in a given time the buffet of many more waves of water than he who stands motionless among the breakers, and similarly with waves of sound.

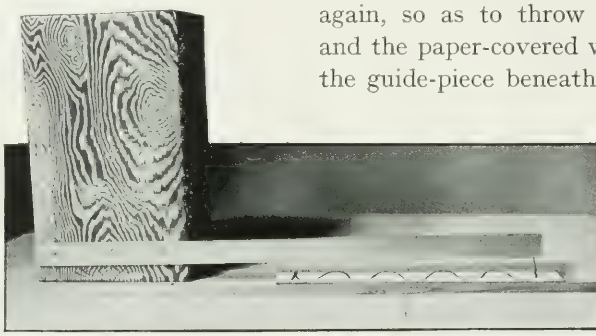

FIG. 7.—A ZIGZAG LINE IS DESCRIBED BY A BRUSH FASTENED TO A ROD WHICH IS VIBRATED LATERALLY.

In many cases the vibrations can be made evident to sight. Thus, the pulsations of a stretched membrane, such as a drum-head, will cause sand placed upon it to jump about. A tambourine treated in the same way will show, by the motion of such particles, the tremor of the air near any sounding body in the neighbourhood of which it may be held. And in a paper read before the Physical Society, it was shown that sound-waves could be made clearly visible on a delicate film of soap and glycerine, subjected by means of a cardboard support to the influence of a vibrating fork or to that of the human voice. Many means have from time to time been suggested of making sound-vibrations self-recording, and two very simple methods are here shown of obtaining records from a vibrating rod and from a tuning-fork.

In Fig. 7 a weighted box has screwed to it a pine lath, which projects horizontally from its base at a distance of about one inch above the table. This rod, capable of lateral vibration, is furnished at its other extremity with a camel-hair brush, dipped in ink. Another lath is nailed down to the table as a guide, and by the side of this is slid a narrow piece of wood, covered with paper, and of such a thickness that the brush charged with ink just touches it. If, when all these arrangements have been adjusted, the lath is pulled to one side and let go again, so as to throw it into vibration, and the paper-covered wood be slid along the guide-piece beneath it, a sinuous line is drawn on the paper, as shown in the illustration. A trace of the same character can be obtained from a tuning-fork by adopting the method shown in Fig. 8. In this case one prong of the fork has attached to the end of it by cobbler's wax a tiny point of metallic foil, and if this be carefully adjusted above a smoked sheet of glass, which can be slid along its guide-piece as shown, a delicate sinuous trace will be cut through the smoked surface by the metallic point.

It has been shown that the sound given by a vibrating body is reinforced by the near neighbourhood of a resonant cavity, but the body of sound is much augmented if the column of air contained in such a cavity be properly attuned to the vibrating body. Fig. 9 is an experiment designed to show this phenomenon. A glass tumbler is partially covered by a small sheet of the same material, and

the size of the opening is varied until, upon bringing the vibrating fork near it, the best result is obtained. If two tubes of cardboard—made by rolling up several layers of pasted paper—be held as shown in Fig. 11, one can be made to answer to the A fork and the other to the fork sounding the note C, by previously tuning the tubes by means of inserted corks, the lower note requiring the longer column of air before it will respond to the vibrations of its fork.*

It now remains to say a few words as to the manner in which sounds are made evident to our sense of hearing. The external ear has little or nothing to do with the auditory apparatus, and in birds, who, it may be assumed, hear as well as mammals, it is altogether wanting. Without entering into the anatomy and physiology of the organ, we may say that the outer passage of the ear is closed by a membrane which measures about one-third of an inch in diameter. This membrane, set in vibration by the sound-waves of the air, communicates its motion to a series of small bones, which in their turn act upon the fluid contents of the internal ear. Within this fluid are spread out the sensitive fibres of the auditory nerve, which conveys to the brain the impression of sound. The transmission is not quite direct. There are certain elastic bristles associated with the nerve fibres, and it is believed that these bristles, which were discovered by Max Schultze, stir the nerve fibres by the vibrations which they take up.

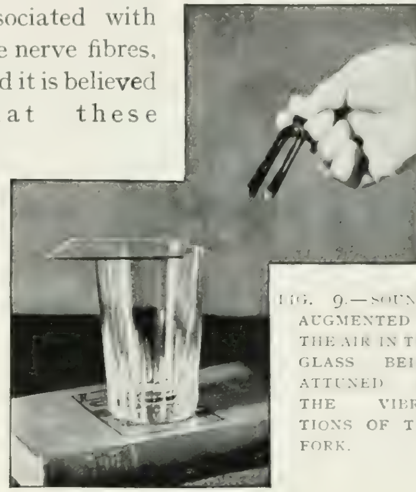

FIG. 9.—SOUNDS AUGMENTED BY THE AIR IN THE GLASS BEING ATTUNED TO THE VIBRATIONS OF THE FORK.

Our appreciation of music seems to be in great measure dependent upon the sympathy with which a vibrating body will act upon another body of equal vibrations. If a sounding tuning-fork be held near another of the same note, and its sound be suddenly quenched, the second fork will sound vigorously, although it has not been touched, except by the trembling air. Two fiddle-strings tuned to the same note will in like manner

FIG. 8.—A GRAPHIC REPRESENTATION OF THE VIBRATIONS OF THE PRONGS OF A TUNING-FORK MAY BE OBTAINED.
A sheet of smoked glass is passed under the fork: a tiny point of metallic foil attached to the latter does the tracing.

* This experiment is suggested in Hopkins' "Experimental Science." For some of the other experiments I am indebted to Alfred M. Mayer's excellent manual, "Sound."

act upon one another. Now, in the internal ear we have a wonderfully delicate organ which follows the same law. It consists of a number of fibres—indeed, we might describe it as a harp having thousands of strings. It is supposed that each of these strings is sensitive to a certain musical pitch, so that when we are listening to orchestral music, each chord that we hear as a compound whole is unravelled, as it were, by our ears into its constituent tones, each tone there seeking out its counterpart, and urging it into sympathetic vibration.

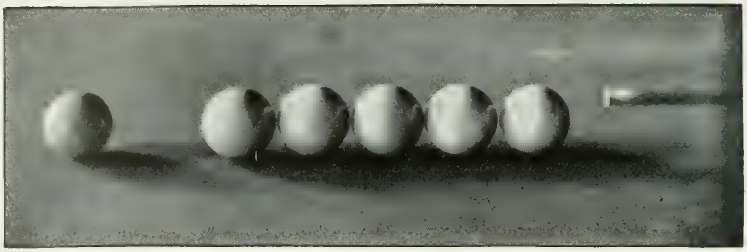

FIG. 10.—SHOWING HOW SOUND IS PROPAGATED THROUGH THE AIR.

Fig. 10 represents a row of billiard balls, the right-hand one of which has been struck with a cue. The left-hand ball flies off from the others as the result. This experiment is instructive, in showing what happens among the air particles when a sound wave passes: the original impulse is transmitted from particle to particle until the ear is reached.

It must be understood that we have in this paper taken a necessarily brief and very general view of the subject of sound. The different headings which it embraces are so extensive in their bearing, and so intricate in their investigation, that they might each form matter for many pages. By taking this general view of acoustical science we have at least paved the way for the future more detailed consideration of various phenomena connected with the sounds we hear.

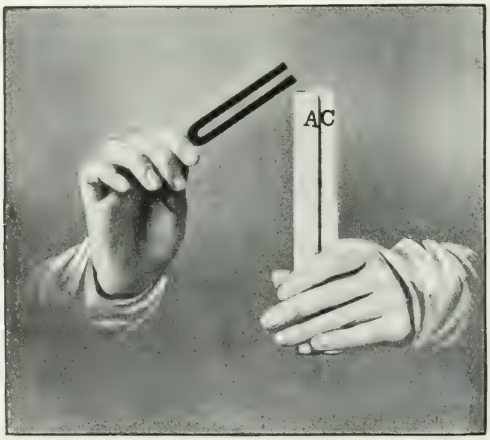

FIG. 11.—TWO TUBES OF CARDBOARD (A AND C) MAY BE "TUNED" BY INSERTING CORKS TO ANSWER TO AN "A" FORK AND A "C" FORK RESPECTIVELY.

THE ORIGIN OF OUR DOMESTICATED ANIMALS.

APART from the interest naturally attaching to the domestication of the different animals which man has chosen to live with him and minister to his wants, the investigation into the time when he first adopted each, and the manner in which they gradually became tame, is of great importance in tracing the early fortunes of the human race. Civilisation went hand in hand with man's obtaining animals to subdue the ground and supply him with more of the conveniences of life. Thus a study of the domesticated animals and their origin demands a study of the early inhabitants of Europe, of those primitive cave-dwellers and occupiers of houses supported on piles driven into the lakes, who have been revealed to us by science as the immediate ancestors of historic man. An inquiry, therefore, into the origin of domestic animals compels us to go back to the days of the world's youth, when Europe was much of it covered with a perpetual ice-sheet, and extinct elephants, cave-bears, rhinoceroses, and the like roamed its trackless forests, and reared their young where now stand the proudest capitals of the world. It must be remembered, too, that Great Britain, during much of this period, was united to the Continent, and so no one need be surprised at elephants' teeth being dredged up off the Norfolk coast, and at the motley assemblage of wild beasts brought to view in the hyena's cave at Kent's Hole. The bones, the tools of stone and bronze, and the like, found in the mud of lakes where were man's dwellings in those prehistoric times, or in the barrows where his tribesmen laid him at rest, will greatly help these investigations. Again, bones and other remains of the domesticated cattle of hundreds of years ago are not unfrequently at the present day found in peat mosses and similar localities. Just as the precious translucent jade, which is so eagerly prized both by primitive and civilised man, must have been brought into Europe from China, so the earliest glimpse we can obtain through the dim haze of long distant ages into the history of our domestic animals leads us to think of the tribes of wandering Tartars who at present inhabit the great deserts of Northern and Central Asia, and of the wandering Arabs of southern and warmer climes, who all adopt the nomad life and take their domestic animals with them from place to place.

These thoughts lead inquirers to a still remoter antiquity, and they see the first travellers from the cradle of the human race finding their way, after the dispersion of mankind, into Europe. The home of primitive man was doubtless somewhere on or near the plateau of Pamir, whence a stream or streams of migration descended upon Hindostan on the one hand and towards Europe on the other. Travelling westwards and south of the Caspian, in all probability, our ancestors made their way through Armenia and Asia Minor, and so over the Bosphorus near Constantinople. It was easy for those who pushed still farther west to the Pillars of Hercules, and then north till they were confronted by the white cliffs where now stands Dover (supposing that Great Britain had then assumed an insular position), to cross the intervening straits, just as daring barbarian navigators impel their canoes at the present day from their homes in one Polynesian island to another.

America itself was peopled, long ages before Columbus, by means of voluntary exiles or storm-driven refugees carried to its north coasts from Asia by Behring Strait. Naturally but few domestic cattle would accompany these early pioneers of civilisation; they would gradually domesticate and improve the breeds of such animals as they found useful amongst the indigenous inhabitants of the district. Thus the dog, as we now know it, might well spring from several or many wild types, and the European—or rather Asiatic—sheep be crossed with an American representative of the *Ovidæ*.

Man in a hunting society preceded man as a tiller of the ground; consequently, one of the earliest animals which he might be supposed to domesticate would be the dog, which would serve as a companion on his hunting expeditions and assist him in finding and securing his game. The dog was the friend of man in very early times, and, although there is no direct evidence of the fact, it is presumed that the dog was, if not the first, at least amongst the first of the wild animals tamed by man.

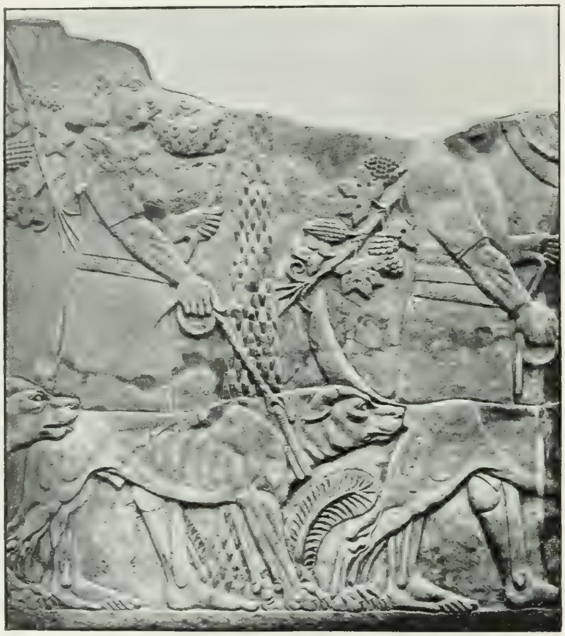

FIG. I.—ATTENDANTS WITH DOGS. *(Assyrian.)* *From a photo taken in the British Museum.*

The great question with regard to the dog is one which the vast diversity of its breeds naturally suggests: Is it descended from one wild ancestor, such as the wolf, or from several? At the earliest known historical period several breeds are found existing, very unlike each other, and closely resembling those which we possess at present.* A glance at any illustrated book on the Assyrian and Egyptian remains will show this (Figs. 1 and 2). Compare these dogs with a modern type such as that depicted in Fig. 3. "But long before the period of any historical record the dog was domesticated in Europe. In the Danish middens of the Neolithic or new stone period bones of a canine animal are imbedded," and it was ingeniously argued by Darwin that these belonged to a domestic dog, for a very large proportion of the bones of birds preserved in the refuse consists of long bones, which it was found on trial dogs cannot devour. The North American Indian dogs at the present day are like North American wolves, and are still frequently crossed with them. Eskimo dogs, too, resemble the Arctic wolves. In Europe many Continental shepherd dogs closely approximate in appearance to the wolf. The wolf must therefore be deemed the parent of the dogs of the West. As for Eastern dogs, they may well have sprung from the jackal, so common in hot countries. Much pains

* Darwin: "The Variation of Animals and Plants under Domestication," Vol. I., p. 16.

were taken in these investigations by Darwin, and he considered that several species of wolves and jackals must be regarded as the ancestors of the dog, unless we are to accept Professor Huxley's dubious hypothesis of the dog having, like the horse, a still more remote ancestry, which must be sought for in the dry bones of Tertiary rocks.

Curiously enough, the habit of barking, which is almost universal with domesticated dogs, does not characterise a single species of the family in a wild state. It is said, too, that when dogs relapse into a savage state they lose their habit of barking. Climate, again, appears to modify the forms and disposition of dogs. It is for this reason that English hounds when sent out to India rapidly decline both in bodily constitution and characteristics, while bulldogs lose their pluck and ferocity after two or three generations, and even their under-hung jaws. It is curious, too, how long the dog retains the habits which tell of his wild ancestry. Thus, however well and regularly fed he may be, he often buries, like the fox, any superfluous food ; and he never lies down deliberately on the hearthrug without first turning round and round, as if to trample down sufficient grass to form a bed, just as his far-away ancestors used to do in their native forests.

Although wild cats still exist in the north of Scotland, and were at one time fairly common throughout this country, it has long been known that our domestic cat is not indigenous to these islands, but is descended from an Eastern stock. Cats were early domesticated in the East, and in Egypt their antiquity is shown by monumental drawings and their mummied bodies. These Egyptian feline mummies belong to three distinct species of cats, of which two are still found both wild and domesticated in parts of Egypt. The legend of Dick Whittington points to the foreign origin of the cat, for a tamed specimen of the wild species would have been neither rare nor valuable at that time, while the excessive penalty attached to killing the king's cat by the ancient Welsh laws is also suggestive of its rarity. Some have fancied that the name " puss " hints of a Persian origin, but it is quite as probable that it indicates Egypt as the source. Islands, and countries that are completely separated from each other, possess distinct races of the domestic cat. This may be owing in some measure to different conditions of life, but it is no doubt mainly due to their being descended

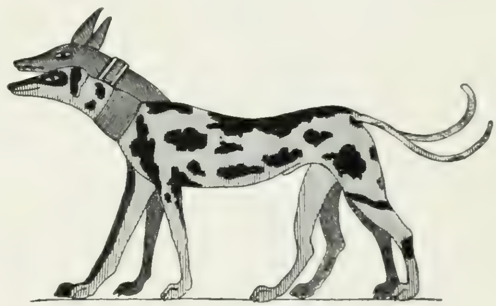

FIG. 2.—GREYHOUNDS.
(Egyptian.)

from—or at least having been crossed with—several aboriginal species. Manx cats are tailless. In the Malay Archipelago the cats have short tails—about half the ordinary length—often with a sort of knot at the end. The cats of Ceylon are small, and very different from the English variety in the size and shape of the head and ears. It is highly probable that the domestic cat of this country is the result of crosses between the imported forms and the indigenous wild cat. These animals interbreed at the present day, and the hybrids have been kept in domesticity.

The ancient ancestry of the horse has been worked out with a considerable degree of certainty, but when or where he was first subjugated by man is not known. If we trust our own ideas of what would happen in the infancy of

civilisation, the taming of the horse would follow closely upon that of the dog. It appears natural to expect that the horse would be tamed quite early, and be ridden by man in his vocation as a hunter and in his encounters with enemies. It seems, however, that long after man had commenced to desert the nomadic life, and the tendency to settle in villages and cities had set in, the horse was never ridden by him, but was regarded only as a beast of burden (Fig. 4), and useful in war for drawing the chariots. In the Homeric poems the horse is never employed to help man in hunting. Remains of the horse in a domesticated condition have been found in the Swiss lake-dwellings belonging to the Neolithic period. Neptune produced the horse from the earth by striking it with his trident, said the Greek myth. This looks as if the animal had been transported to Greece by sea. No truly wild horse is at present known to exist, though in the steppes of Western Asia there exists a species (*Equinus Prjevalskii*) which is considered by some authorities to be an aboriginal wild one. If this is not a truly wild horse, it is probably the closest relation to it which is known. The colour and markings of this animal are those we are accustomed to regard as "reversion" to an ancestral type when they occur amongst horses bred in this country. The wild horses of the East are commonly supposed to be sprung from escaped animals, and those in America to be descendants of the horses taken over by the Spanish conquerors, the bones of the original horses of the country being found in a fossil state. The size and strength of our own Shire and Clydesdale horses, and the thoroughbred race-horse, exemplify the power of careful breeding in improving this animal and adapting it to special requirements.

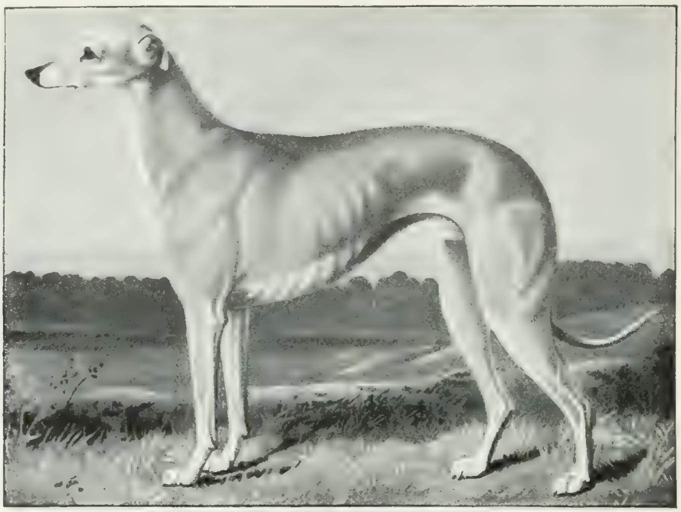

FIG 3.—GREYHOUND LAUDERDALE, THE PROPERTY OF MR. TOM SHARPLES.
No domestic animal exhibits more variety than the dog, but the greyhound is one of the highest developments of all. Compare with the older type shown in Fig. 2.

As for the donkey (Fig. 5), there is little doubt of his having sprung from the wild ass still found in Nubia and Abyssinia, commonly known as the Nubian ass. The donkey, too, varies greatly in size and appearance. One of the breeds of the south of France is almost as tall as an average horse, while in Western India the donkey is not much larger than a Newfoundland dog, "being generally not

more than from twenty to thirty inches high." In our own country the animals are by no means uniform in appearance, but there are no distinct breeds. This is not due to the fixed and unchangeable character of the race, but is owing rather to its being bred only in small numbers and by poor persons, who take little care in the selection and mating of the animals.

From investigations regarding the genealogy of the pig, it appears that there were two parents—the wild boar (Fig. 6) and the Chinese pig. The wild boar has a very wide range of distribution; it occurs throughout the temperate and hot districts of Europe, Asia, and Northern Africa, and became extinct in England only in recent times. Sir T. Cumberworth, a Lincolnshire knight, when making his will in 1450, leaves his "bor sper" to a friend as naturally as might a captain quartered in Bengal. Pigs descended from the wild boar were kept by the Swiss lake-dwellers, but at what period the varieties which formerly existed in this country came into being we do not know, though we are aware that in Saxon times swine were kept in large numbers.

The wild boar is strong, fierce when attacked, and capable of rapid movement over difficult country; his outline and general qualities do not indicate a profitable animal for the production of high-class bacon. When the animal is domesticated his outline changes in the course of a few generations; he becomes more greedy and less particular in the matter of food, and fattens more readily.

FIG. 4.—KING'S CHARIOT AT THE CAPTURE OF A CITY IN SUSIANA BY ASSUR-BANI-PAL.

From a photograph taken in the British Museum.

The Chinese pig is small, with short limbs and face, and possesses remarkable aptitude for fattening. It has been domesticated and carefully tended for a longer period than our own native race, and was introduced into Britain and crossed with the aboriginal varieties when trade with China was first developed. The Chinese are particularly careful of their pigs, take great pains in feeding and tending them, and will not even suffer them to walk from place to

FIG. 5.—THE HUMBLE ASS IN EGYPTIAN TIMES.
The ass has been used as a beast of burden in Eastern countries from time immemorial.

place. There is far more difference between a well-bred Berkshire pig (Fig. 7) and a wild boar than between a modern donkey and the Nubian ass. A singular breed, said to have formerly existed in the central islands of the Pacific Ocean, is described as being of small size, hump-backed, with a very long head, short ears turned backwards, and a bushy tail not more than two inches long.

Just as our dogs and pigs are the descendants of more than one wild form, so cattle fall under two great divisions—the humped kind, inhabiting tropical countries, and the common non-humped cattle. The humped cattle were domesticated at least 2,000 years before Christ, according to Egyptian monuments. They have at present many different characters from the ordinary breeds. They grunt rather than bellow, "seldom seek shade, and never go into the water and there stand knee-deep like the cattle of Europe." They have run wild in parts of India, and can maintain themselves in regions infested by tigers. They are best known to us in the form of the sacred Brahmin bulls which walk about Eastern streets, and which it is the height of impiety to drive away from favourite spots or in any way to molest.

FIG. 7.—A BERKSHIRE PIG.
The pig is proverbially the type of greed. This greed has been an important factor in the evolution of the animal. In domesticity the pig fattens readily, the size of the body increases, and the relative length of the leg and the snout decreases.

FIG. 6.—A WILD BOAR.
Compare with Fig. 7.

Turning to the humpless breeds, at least nineteen well-marked varieties are found in Great Britain alone, and in the period before any systematic improvement in the breeding

of live stock had taken place there were probably as many as sixty. Fossil remains of two types of oxen occur in this country. One of these was of gigantic size ; its remains indicate a length of twelve feet and a height of six and a half feet. It attained its greatest development in the Pleistocene or Ice Age, and was the contemporary of the mammoth, rhinoceros, and other large animals. It probably became extinct in this country before the Roman invasion, but on the Continent it persisted, and was the parent of the breeds of cattle which occur at the present time throughout middle Europe. After the departure of the Romans, when Angles and Saxons settled in the country, this type of animal was re-introduced by them, and many of our breeds (Fig. 8) are descended mainly from it. Some of these animals escaped into the forests, and their descendants have remained in a wild state to our own times. A herd of them is to be seen in the park of Chillingham, in Northumberland. Many will remember Sir Edwin Landseer's fine picture of these cattle, painted not long before he died (Fig. 9). These animals are white, with the inside of the ears reddish-brown ; the hoofs are black, and the horns white, tipped with black. At certain times they are very dangerous to strangers. Several other British parks have the same breed. When oxen escape and become wild on desert islands, it has been noticed that the ears of their descendants almost always turn reddish and their skins white, like these oxen.

The other type of animal whose fossil remains are found was of small size, and had a short body, with small horns and fine legs. It occurred as a domesticated animal in Great Britain at a very early period, and furnished food for the Roman legionaries quartered here. It was also very common in Switzerland during the existence of those races of men who used polished stone weapons. When the native Britons retired to the north and west of the country, they took some of their cattle with them, and the descendants of these are seen at the present day in such breeds as the small Welsh, Kyloe or West Highland, and Kerry cattle.

Of the more useful domestic animals, sheep and goats yet remain to be treated. From a very early period sheep have been domesticated. The Swiss lake-dwellings have disclosed remains of a small form, with thin legs and horns like a goat. This species differs somewhat from any now known. The breeds of sheep, like those of cattle, possess many distinctive features—horns or their absence, longer or shorter fleeces, and the like. As for the ancestors of our domestic sheep, it is impossible to trace them. Authorities differ very considerably on this point. Bones of true sheep occur in prehistoric rubbish heaps, but whether the animals were domesticated or not is uncertain. The sheep is essentially an animal of the hills, and in the past its power of leaping and climbing the rocky hillsides would be of great service in aiding its escape from its enemies.

" In Switzerland, during the time of the lake-dwellers, the domestic goat was commoner than the sheep, and this very ancient race differs in no respect from that now common in Switzerland."* It has certainly come, like so many other domestic animals, from the mountains of Asia, where a wild goat (*Capra ægagrus*), from which our domestic goat is believed to be descended, yet lives. The differences in size, length of horns, etc., among domestic goats are very great ; but the animal reverts to wild life with much facility, and has been known in Scotland in a very short time to become as suspicious and fleet of foot on the mountains as a red deer, so that it had to be stalked and shot with a rifle. Indeed, it has there

* Darwin : " The Variation of Plants and Animals under Domestication," Vol. I., p. 105.

been recommended as a substitute for deer. No really wild goat, however, is found in Europe. The animal came in with the men who first settled on the Continent from Central Asia.

One more quadruped remains—the rabbit, so frequently kept by boys. It is descended, there can be no doubt, from the common wild rabbit, but is much modified by confinement, selection, difference of food, and similar conditions. Hence come all those monstrous forms of the ears which are termed "lops" and "half lops." The rabbit was early domesticated, and the changes it is capable of undergoing may be estimated from the fact that an English lop-eared rabbit has been exhibited which weighed eighteen pounds, whereas a wild grey rabbit weighs only about three and three-quarter pounds. In 1869 another lop-eared rabbit was shown whose ears measured from the tip of one to the tip of the other $23\frac{1}{8}$ inches in length and $5\frac{1}{2}$ inches in breadth. The length of ears in a wild rabbit is $7\frac{5}{8}$ inches. When tame rabbits of any colour are set free in Europe they generally revert to the original grey of their ancestors.

FIG. 8.—A GOOD TYPE OF PRIZE SHORTHORN.

To turn now to the common birds which have been reduced to subjection by man and taught to stay near his abode. Perhaps pigeons first invite attention. When their variety, curious habits, and fantastic appearance are duly considered, from the fantail, the pouter, the carrier, the Indian tumbler (which tumbles on the ground), the English tumbler (which turns somersaults in the air), and many other singular varieties, it is at first scarcely credible that they should all have sprung from one ancestor, the common blue rock-pigeon of our maritime cliffs; yet so it most certainly is. Careful selection and breeding produced all these widespread divergences, aided, no doubt, by the fact that domestic pigeons do not usually receive their naturally varied diet, and have often been transported from one climate to another. A voluminous literature about the pigeon has sprung up both in European and Oriental languages, and an immense body of observations on it has been accumulated by fanciers, as Mr. Darwin says, "for some five thousand years." These breeders all find that the white tail-feathers of the wild rock-pigeon are continually reappearing in their most careful strains. Nature will maintain her own colour and fashion. From this and other indications there can be little doubt that in the pigeon which darts out of the sea-caves at the approach of a visitor in the northern parts of our island the origin of all the varieties may be seen.

Similarly the ancestry of all our domestic fowls may be traced from the jungle-cock of Northern India (*Gallus Bankiva*). Everyone is familiar with the surprising differences between black Spanish fowls

FIG. 9.—THE FATHER OF THE HERD: THE CHILLINGHAM BULL.

[illegible]

and Dorkings, Polish fowls with frizzled crests and the diminutive bantam; yet all have been produced from the same wild fowl of the Indian jungles. Remains of the fowl have been found among prehistoric relics and extinct animals, but it is not figured on the ancient Egyptian monuments. It apparently reached Europe in a domesticated condition somewhere about the sixth century B.C. Julius Cæsar found it in Britain on his arrival.

Our ducks are descended, without a doubt, from the common wild duck, which has a wide geographical range—from North America to Bengal. All country folk are aware that wild and tame ducks will breed together, and that birds so bred from the wild ones are much better for the table than ordinary barn-yard ducks. They are, however, somewhat difficult to rear, and deteriorate in the course of a few generations. It is singular that young ducks, even when bred from the eggs of wild birds, often suffer when allowed to go into water at a tender age. We have known one duckling thus put into its native element when about three days old, and suffered to swim. Kindness killed it, and it died of the immersion. This is said, however, to be a well-known difficulty in rearing young ducks. On the other hand, in a wild state they take to the water at once, and that with impunity.

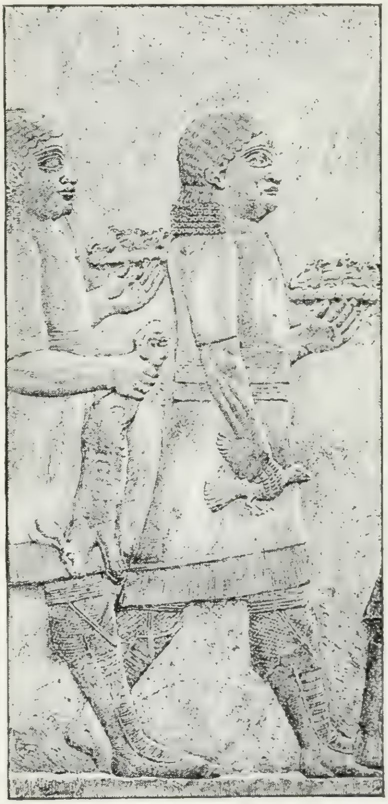

FIG. 10.—HARE AND BIRDS.
(Assyrian.)

The next inmate of the poultry yard which calls for attention is the goose. It is manifestly sprung from the common wild goose (*Anser ferus*), which is easily tamed. The goose (Fig. 11) was domesticated in Homer's time, and was kept in the Capitol at Rome as being a bird sacred to Juno. The cackling of geese once saved the city under critical circumstances, as all will remember. As the goose arrives at a goodly size and flavour by nature, domestication has not been put under requisition to produce many varieties, so that this bird has been singularly little changed from the earliest date of its being kept by man. The peacock comes from the jungles of India, and is another bird which has scarcely varied under domestication, except that white or piebald specimens are not uncommon, just as pheasants vary at times. Perhaps the plumage of our tame peacock is rather thicker than that of the wild bird, but no other differences between the two can be discovered. "Whether," wrote Mr. Darwin, "our birds are descended from those introduced into Europe in the time of Alexander, or have been subsequently imported, is doubtful."

The turkey is descended from two parent forms—the Mexican variety and the wild turkey of North America. These latter birds have been frequently kept in England during recent years. The

guinea-fowl inhabits extremely arid districts in Eastern Africa, and has hardly varied at all under domestication, except that the plumage becomes either paler or darker in colour. The parent bird is *Numida ptilorhynca*. The guinea-fowl even now cannot be reared in a damp climate, and loves to lay its eggs away from home in exposed situations, choosing by preference those facing the east, doubtless from some inherited predilection for its old desert life.

The history of our domesticated animals seems to point out that man tamed for his own purposes first the dog, next the pig, then the ox. The fact that they have so largely improved under his fostering care does not authorise any manner of cruelty, neglect, or thoughtless usage of the lower animals. He who is most impressed with the long ancestry of our domestic animals, with the benefits they confer on us, is the least likely to behave cruelly towards them. They demand, in return for the benefits they give us, kindness, humanity, and consideration. As with care animals are capable of improvement by man, so he who acts cruelly towards them himself retrogrades in the rank of creation—

"Puts off his generous nature, and to suit
His manners with his fate, puts on the brute."
Cowper.

FIG. 11.—GEESE.
(Assyrian.)
The cackling of geese once saved Rome, but the goose was a "domestic" long before the Roman Empire came into existence.

SOME FEATHERED TRAVELLERS.

1. NIGHTINGALE. 2 SWALLOW. 3. SPOTTED FLYCATCHER. 4. REDSTART. 5. RED-BACKED SHRIKE. 6. CUCKOO. 7. GOAT-SUCKER. 8. CHIFF-CHAFF.

THE MIGRATIONS OF BIRDS.

THERE are few more interesting and improving studies in connection with the natural history of animals than that which deals with the social habits of the feathered tribes. It is an inviting field of inquiry in several respects, but more especially with reference to such birds as are called *migratory*, in consequence of a disposition to change their retreats at certain seasons.

This migratory habit is by no means confined to birds. Many fishes migrate—witness the travels of the salmon and the sturgeon; whilst amongst reptiles turtles display the "moving" instinct to a marked degree. The travels of mammals are naturally restricted by the ocean, but the Alpine hares, the Arctic fox, and the reindeer are all confirmed travellers.

FIG. 1. THE FIELDFARE.

This is one of our most distinguished winter guests.

Subject to none of the restrictions which govern the movements of terrestrial animals, birds are the greatest migrants of all, and thus afford us the greatest facilities for studying this curious periodical shifting of quarters.

That many birds—such, for instance, as the swallow—leave us, upon the approach of the cold weather, to winter elsewhere, and return with the more congenial weather in the spring, is a matter of common knowledge, but this is only one fact amongst the many which are included in this complex subject of migration. Speaking generally, we may place the feathered travellers in three sections, according to their behaviour. Thus, in Britain we have:—

(1) The summer visitors, such as the cuckoo, goat-sucker, nightingale, red-backed shrike, redstart, spotted fly-catcher, and swallow (Coloured Plate), which leave us at the approach of winter and go elsewhere.

(2) The winter guests, such as the woodcock, many ducks, fieldfares (Fig. 1), and red-wings, which leave their Arctic breeding places to winter in our comparatively genial climate. These journey northward again in spring.

(3) The callers, which, breeding in the north and wintering in the south, take the British Isles as a resting-place or half-way house upon their long journey. To this section of bird casuals belong the sandpipers.

The general trend of bird migration is towards the equator in winter, towards the poles in spring or summer; but this statement is far too general to be strictly true in all cases. Thus the course followed by some birds is very nearly circular. Again, our winged visitors have their capricious moments; witness the woodcock (Fig. 2), which comes to winter, falls in love with our climate, and stays next summer to breed.

Many of the causes which have prompted this great coming and going of birds at various seasons are obscure, but it would seem as if the two main factors are *food supply* and *climate.* But the swallow (*see* Coloured Plate) leaves us long before insect life has become scarce; possibly it is the weather

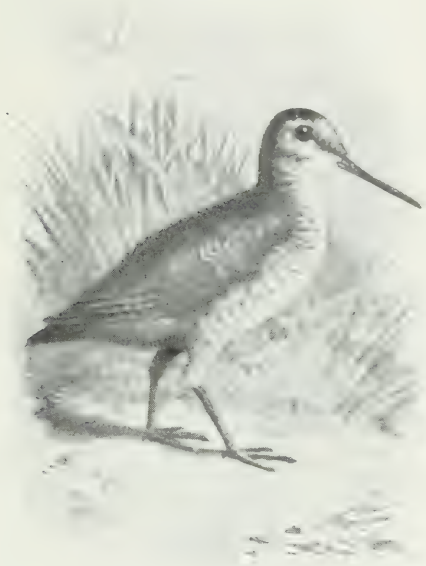

FIG. 2.—THE WOODCOCK.

A capricious visitor who is not insensible to the allurements of the British climate, and prolongs his stay.

that he has his eye upon. Like the experienced traveller that he is, he does not wait until the last moment to make his arrangements. He leaves us whilst yet the memory of his stay here is a pleasant one, and departs to his sunny central African winter quarters before the food supply is curtailed. But all the regular migratory birds are insect-eaters, or nearly so, and spend the summer in one country and the winter in another. They come and depart with considerable regularity as to time, and journey after definite methods. Thus the spring and autumnal equinoxes herald their arrivals and departures; and whilst some fly in flocks, others proceed singly. In fine, each species adopts a particular mode of travelling; and year after year, for unreckoned ages, has this coming and going been continued more or less throughout great portions of the globe.

During March, April, and May an observer on the southern and eastern shores of our islands—or, in fact, anywhere along the routes pursued by birds of passage—may note many interesting facts connected with their times of arrival, and the order and punctuality of their movements.

"Beautiful birds of lightsome wing,
Bright creatures that come with the voice of spring."

The sprightly black-cap (Fig. 3), the wryneck, with its almost uncanny snaky twisting of its tiny body (Fig. 4), and the natty little pied wagtail (Fig. 6), may be confidently looked for. Now if the movements of the birds showed no further points of importance than the advancing and retiring within moderate limits, according to their needs, there would be little in their sojournings to create wonder. But this is far from being the case. Some birds perform prodigies in the extent of ground journeyed over, and in the rapidity of their movements. The tiny ruby-throated humming-bird of North America proceeds annually from Mexico to Newfoundland and back; and the majority of our summer songsters cross and re-cross the Mediterranean. The common black swift, so frequently observed circling around church spires and tall buildings, leaves Northern Africa in March and April, when the climate is genial and there is apparently no falling off in insect food to necessitate its departure. Nevertheless, it leaves abruptly, and reaches England and Scotland about the beginning of May. It does not appear to push to the northern limits of its migration with rapidity, possibly on account of the climate of the north being not yet suit-

able. Portions of the host settle down on the islands and along the northern shores of the Mediterranean; and, whilst

FIG. 3. THE BLACK-CAP.

This sprightly little visitor comes in April and leaves in September. It has considerable talent as a warbler, and likes an elevated position to sing in. The conspicuous black hood gives it its popular name.

the mass is spread over central Europe, the remainder proceed farther northward, until a few reach the Orkney and Shetland Islands. No sooner, however, is the choice of a locality made, than the parental duties are undertaken. The young are hatched by the end of May, and become strong and fly about by the beginning of July; then the broods assemble, and, after a few weeks spent in vigorous evolutions, as if training for the long journey, they suddenly vanish—

> "Like the Borealis race,
> That flit ere you can point their place."

A week afterwards they may be seen circling around the ruins of ancient Thebes, the walls of Jerusalem, or the minarets of Morocco.

The powers of flight of the swifts are not surpassed among the feathered tribes. It has been computed that the greatest speed of the common black swift of Europe is about 276 miles an hour, which, if maintained for about six hours, would carry the bird from its summer retreat in England to its winter home in Central Africa. The large purple swift of North America is, to all appearances, still stronger on the wing. The chimney swallow is said to attain a maximum rapidity of flight equal to about ninety miles an hour; whilst the passenger pigeon of North America is believed to travel at the rate of about one thousand miles a day. There can be little doubt that an instinctive impulse comes over the bird of passage at the time of its departure from its winter and summer retreats. This is manifested in various ways. For example, many species, such as the common house martin, have been known

FIG. 4. THE WRYNECK OR CUCKOO'S MATE.

[illegible]

repeatedly to abandon their second broods in autumn, and leave them to perish miserably, the migratory instinct—or perhaps, rather, the instinct of self-preservation—overcoming parental affection. Indeed, this yearning to depart

seems innate in the constitution of the bird, inasmuch as the young of migrants brought up from the nest, and apart from their parents, display much restlessness at the seasons of departure of their brethren. Now, it will be apparent that, although failure of food in autumn is no doubt the chief factor in the movement at that season, to the same cause cannot be attributed the bird's departure from its winter retreat in the warm climate of Northern Africa in spring, when insect life is equally—if not more—plentifully distributed than during the preceding months. It is consequently this anomaly that constitutes, with the distance travelled, the marvellous characters of the movement in question. The parental duties have been supposed to hasten the spring departure, but there is no evidence of a trustworthy nature to show that birds display any disposition to pair until they have reached the breeding-grounds. It is to be observed, however, that a pronounced change of climate takes place in all regions frequented by the regular migrants of temperate zones. In North Africa the winter crops are gathered in spring, when the genial climate of the previous months begins to change, and verdure to wither before the hot blasts from the Sahara, which give warning of the approach of the fierce heat of summer. Accordingly, many birds assemble in flocks, and proceed towards the coast; and possibly the cooler breezes from the north may beckon them back to the lands from which in autumn they had been the signals for their departure.

The retreat of the migrant from its summer home is generally more leisurely performed than the advance in spring; but a great deal depends on the food, habits, and constitutional susceptibility of the species. Some birds start much earlier than others, and individuals linger for weeks after the majority of their brethren have departed. The quail (Fig. 5) is a great vagrant, especially along the countries of the Mediterranean, where, as soon as the spring produce has been reaped, large flocks of quails cross the inland sea for Europe, pursuing the same course as when they "came up and covered the camp of the Israelites." Like other birds of passage, they are comfortably plump and fat at the time of their journey, and, in consequence, are greedily sought after by the southerners, who wage a destructive warfare, not only on them, but also on all the smaller birds. The far-famed *beccafico* of the Italians is no other than the pretty little garden warbler, which is considered to be a most delicious morsel. However, when sufficient numbers of the latter cannot be procured, almost every other small bird of passage is substituted, including that prince of songsters the nightingale, thousands of whose dead bodies may be seen on the tables of the poulterers.

The sudden disappearance of the swallows was a subject of wonder even so late as the end of the eighteenth century, and various explanations were advanced. By certain naturalists it was asserted that they never left the country, and spent the winter at the bottoms of lakes and rivers in a state of torpidity; and even at the present day it is believed a few may hibernate in certain localities; but no authenticated instances have been adduced. The opinion may have originated in the not unusual occurrence when loiterers in autumn are caught by the cold, and become benumbed. One of the most remarkable European migrants is the cuckoo (Coloured Plate). Like the swift, it departs early in autumn, when insect life is still plentiful. The cuckoo, moreover, furnishes another suggestive instance of a migrant, displaying a restlessness, or the migratory instinct to leave the summer retreat as soon as possible; and considering its short stay and very extraordinary behaviour during its sojourn

in Europe, one is lost in wonder to understand why it takes the trouble to come all the way to the bleak north in order to

FIG. 5.—AN INVETERATE VAGRANT: THE QUAIL.

May to October finds the quail represented in the British Islands. Africa is the winter home.

deposit its eggs in other birds' nests, and depart soon afterwards. The cuckoo crosses from Africa in March and April. No sooner is the summer home gained than the well-known call announces its arrival, and as soon as the eggs are deposited in the nest of some unsuspecting hedge sparrow, titlark, or wagtail, then the "messenger of spring" begins to get hoarse, then ceases to chaunt, and begins to think of beating a retreat southwards.

> "In April, the cuckoo shows his bill;
> In May, he sings both night and day;
> In June, he altereth his tune;
> In July, away he'll fly;
> In August, go he must."

Altogether, the British visit does not extend over three months, so that if the cuckoo built a nest and reared its young, there would be very little time to spare. But there is this peculiarity in the mode of laying the eggs: each egg is deposited in another bird's nest, and at intervals of two or three days. Consequently, the young are of considerably different ages.

Now, if the parents reared their young, the latter would be of all ages, and the older would be fledged and flying before the youngest could leave the nest; so that under these conditions the arrangement seems extremely well adapted to the habits of the cuckoos, which, however, are not the only birds that lay their eggs in the nests of other species. Perhaps, also, the refractory habits of the young cuckoo are enough to prevent the older birds from assuming all parental cares. Shakespeare makes "The Fool" say in *King Lear*, alluding to the daughters of the King:—

> "The hedge-sparrow fed the cuckoo so long
> That it had its head bit off by its young."

Evidently the cuckoo thinks it well to keep its own head out of the way.

FIG. 6.—THE PIED WAGTAIL.

[illegible] in the other wagtails, the [illegible] movement of the tail is [illegible].

The well-known night hawks of the Old and New World, and Australia, also make short stays in their summer retreats.

In the case of our night hawk or churn owl, it deposits its eggs on the bare ground, perhaps for the reason that it has not time to build a nest, seeing that, besides its short sojourn, it moves about only at twilight, during which times the journeys to and from Africa, the procuring of food, and the duties connected with the rearing of the offspring, have to be performed. The almost incredibly long journeys made by birds has already been pointed out, and when considering them we can only wonder that so many of the feathered travellers survive. The method by which they steer their pathless course over ocean and land is a mystery. That many perish is a certainty. Some, exhausted by beating against head winds, are blown to earth or into the sea; others fall victims to the hordes of hawks and gannets that are ever on the watch. Many are dashed to death against the lighthouses that man has placed to warn his fellows of the dangers of the sea. But the lighthouse is anything but a friend to the exhausted birds. Attracted by the light they swarm in thousands about the structure, and the phenomenon portrayed in Fig. 7 is by no means uncommon.

The most wondrous feat performed by migratory birds is that recorded by Dr. Jenner, the discoverer of vaccination. He captured several swifts in Gloucestershire, marked them by clipping two claws from a foot of each, and then set them at liberty. Individuals so marked were caught at their old nests every year for three successive seasons, and one was taken with the indelible mark on its claw even after the expiration of seven years. Carrier pigeons also illustrate the same instinct, but not, however, to the extent displayed by the experiments of Jenner. Other instances have also been narrated of the same swallows having returned annually to their nests of the previous year. It must, however, be understood that the occupants of old nests need not necessarily be the original builders; but supposing that now and then such occurrences take place, as in the case of the swifts, what a marvellous display of intelligence they exhibit! Here we have a bird reared in Great Britain, after two long journeys and an absence of seven months in Northern Africa, returning to the nest of the previous year. Even admitting the powers of flight and acute vision possessed by the swallow tribe, and the probability that the summer home is characterised by certain well-defined landmarks, there still remains the mental effort requisite to treasure up a remembrance of the locality during several months of daily-changing fortunes, not to speak of the work of the two long journeys. It is possible, however, that migratory birds, through long experience and the necessities of their existence, have acquired strong powers of memory in connection with their favourite haunts, seeing that almost every species builds in its own especial situation. The storks repair to the tall steeple, the swallows to eaves of houses, and the thrush builds in the leafy tree-top; in fact, each species selects one situation in preference to another.

No doubt birds are guided to and from their retreats by such landmarks as mountain ranges, coast-lines, and in autumn by the sun. The majority of the migrants of North America follow the Atlantic and Pacific coasts, and many European species cling to the western shore-line, as is shown by the frequent occurrence of individuals alighting on ships; but not a few pursue their journeys at night, and others fly at such high elevations that the physical outlines of continents are not likely to be of much use to them.

It appears, moreover, at all events in many species, that the male birds precede

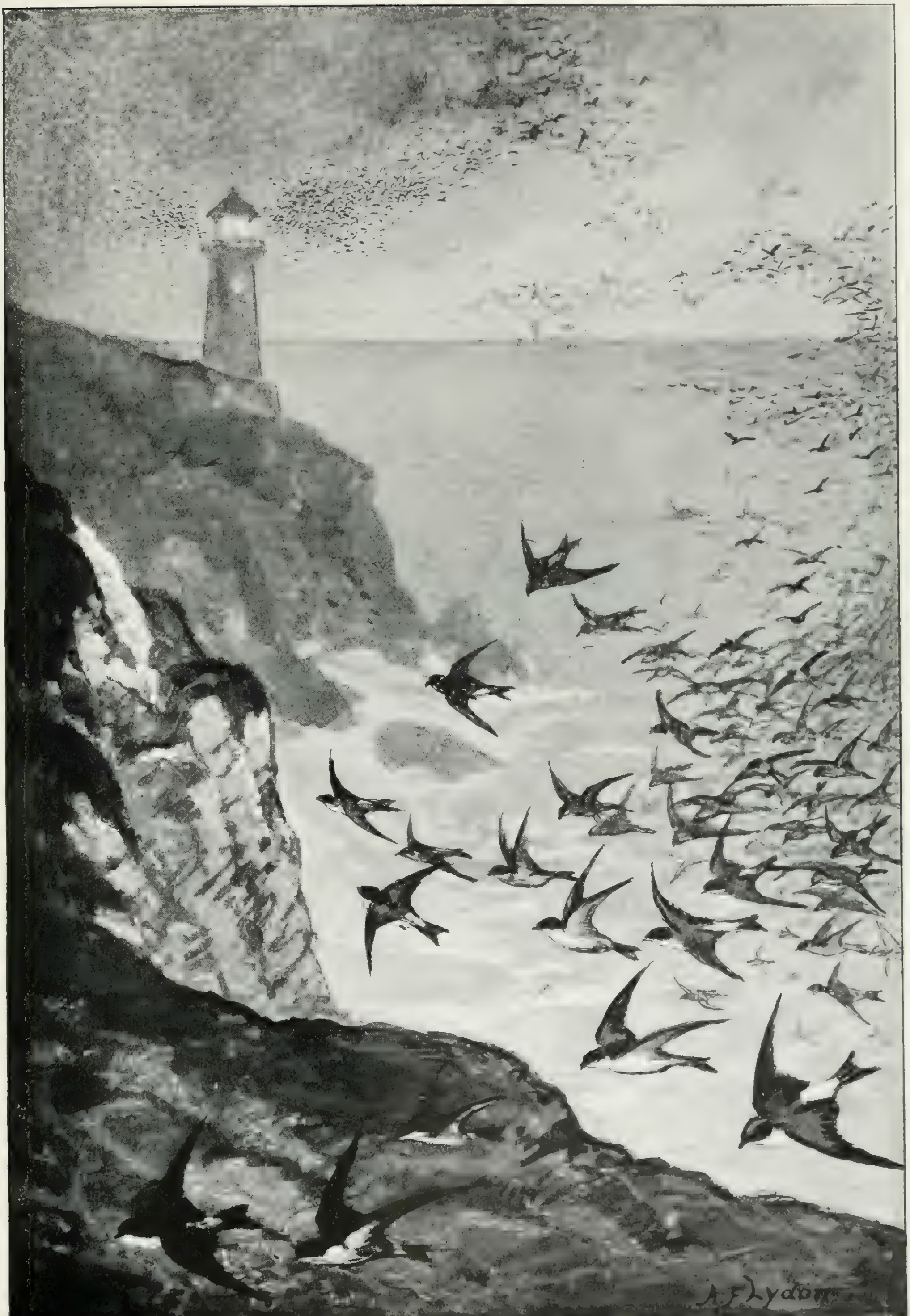

FIG. 7.—"SWIFT BIRDS THAT SKIM O'ER THE STORMY DEEP."

Exhausted by head winds, many of the feathered travellers are blown to earth or into the sea. A lighthouse is an irresistible attraction and also a death-trap. The birds swarm around it, and many are killed by repeated buffetings against the glass.

the female in spring, and that the broods of the year often accompany the parents in the return journey in autumn. No sooner, however, do they arrive at their summer retreat than the choice of a mate becomes the first consideration, and the indigenous as well as migratory birds, which have continued mute during the winter months, now burst into the most fervent outbreaks of song, vociferation, and gesture. The exuberant chirpings of the modestly decked sparrow, the hoarse croakings of the crow, and the musical strains of the nightingale, thrush, and skylark, are the overflowings of happy hearts, excited by the allurements of the vernal season, and doubtless are frequently meant to charm the female. But many birds sing apparently for an occupation, and are excited by rivalry, as is frequently observed in the case of "Cock Robin," whose joyous notes and ever-welcome form announce his presence nearly as often among the frost and snow of mid-winter as in mid-summer: indeed, he may be heard discoursing sweet music in autumn during that very dismal atmospheric condition, "a London fog."

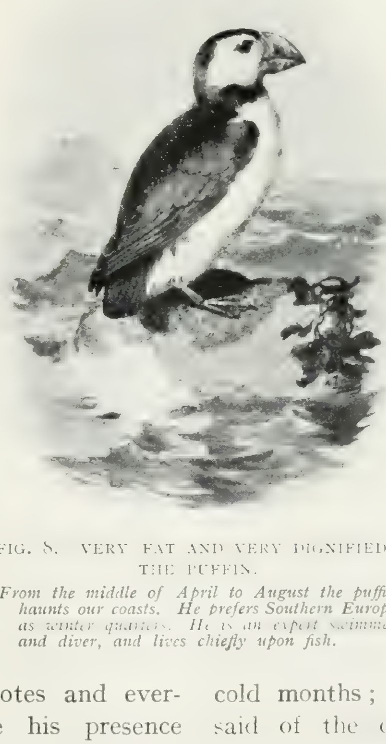

FIG. 8. VERY FAT AND VERY DIGNIFIED THE PUFFIN.

From the middle of April to August the puffin haunts our coasts. He prefers Southern Europe as winter quarters. He is an expert swimmer and diver, and lives chiefly upon fish.

"On the nigh-naked tree the Robin piped,
Disconsolate; and through the dripping haze,
The dead weight of the dead leaf bore it down."

The extent of the migration of birds varies considerably as to time, as well as the distance travelled. For example, the common chimney swallow commences its return movements to Europe early in March, and continues up to the middle of May, whilst almost every swift has passed across the Mediterranean by the end of April.

Again, although the cuckoo appears on the islands and northern shores about the middle of March, it is well on in April before any considerable numbers arrive in the British islands. Indeed, in comparing the dates of arrival of several migrants at Malta and in the north of Scotland, we find that about a month may be allowed between the earliest announcements at these points.

Migrations may be complete or partial—that is to say, all the individuals of a species may abandon their summer retreats, or the greater number may leave, whilst a few may tarry in diminished numbers throughout the winter. All the swallow tribe quit Europe throughout the cold months; and the same might be said of the cuckoo, night hawk, and many warblers; whilst some of the latter retire to Southern Europe, and a few of the wagtails even manage to struggle through our winter by repairing to sheltered situations. Size is no criterion as regards power of endurance, inasmuch as the golden-crested wren, the tiniest of European birds, braves the most severe of Scottish winters. Swallows are very susceptible of cold, and, in common with other sensitive birds, fall victims to sudden accessions of low temperatures, more especially should the latter have

been preceded by scanty supplies of food.

Taking the foregoing phenomena into consideration with reference to the probable origin of birds' migrations, we shall

FIG. 9 THE CORNCRAKE OR LANDRAIL.
The peculiar "crake, crake," of this bird is heard in May.

now try to find their explanation in the history of the areas in which the birds themselves sojourn. As far as historical evidence extends, there is little if anything in the past history of continents beyond certain influences exercised by man on the distribution of animals* to account for the character and extent of many of the migratory movements of birds. It is different, however, when recourse is had to the records of the rocks, for in them we find proofs of changes of the surface, and climates very different in character and extent from anything of the kind now existing in the same latitudes. Confining our inquiries to the northern hemisphere in general, and the European and North African areas in particular—or, in other words, to the regions frequented by the migratory birds of Europe—we find certain considerations worthy of notice. But the subject is too voluminous in its details to allow of more than a brief sketch of the results of patient and diligent researches in connection with the animal and vegetable relics, and mineral components of the various strata composing what have been named the Tertiary Formations by geologists. Going no further back than the Miocene or Mid-Tertiary period, there is very cogent evidence to show that the climate of Central and Northern Europe, even far into the Arctic Regions, was so mild and genial that animals and plants of equatorial latitudes flourished on land and sea. This period, like all other geological expressions of time, was of vast duration, but towards its close the climate began to get colder, and refrigeration steadily increased during the succeeding or Pliocene period until it culminated in what has been called the Glacial Epoch,* when Northern Europe, Asia, and America were shrouded in an Arctic climate. Finally, the Ice Age gradually passed away, and the temperature assumed its present condition. Again, we know, from equally cogent evidence, that the British islands formed portions of the continent of Europe, both before and after the Glacial Epoch; and that Southern Europe and Northern Africa were also joined together by land; so that the migratory birds, as in North America at the present day, might have journeyed over a continuous land-area from Scotland to the Atlas Mountains. At length, changes of level took place, which eventuated in the present physical features of Europe and Africa. Now, what do these data suggest in connection with the history of the

* In connection with birds, the cliff swallow of North America is said to have extended the easterly limit of its migrations from the Rocky Mountains to the east coast within the last one hundred and fifty years.

* The reader is referred to "The Ice Plough," CASSELL'S POPULAR SCIENCE, Vol. I., p. 215, for further information concerning the glacial epoch and its effect upon the land masses.

migratory movement of birds? They indicate—

(1) That the summer retreats and breeding grounds of our migratory birds may have been the permanent homes of their ancestors during the genial climate of the Miocene period.

(2) That as the cold gradually set in, so they retired; at first, just as many of the birds of the Orkney and Shetland Islands now seek our southern shores in mid-winter; but as the cold increased, and vast æons passed away, they retreated still further south over continuous areas, even to their present limits.

(3) As the Glacial Epoch began to decline, so they advanced, and whilst Ireland was gradually separating from Great Britain, and the latter from the Continent, and the Straits of Gibraltar and the great Inland Sea were forming, they still continued their comings and goings, year after year, for unreckoned ages.

From this point of view, what is called the "instinct" of migration appears to be nothing more than an inherited habit which has become modified to the extent exhibited by our native birds in consequence of their adapting themselves to circumstances; whilst such as the swallows and other purely insectivorous birds have no alternative than to retire when their food supplies fail them. This hypothesis, moreover, explains the tendency to migrate southwards in many resident birds, and also the general disposition to return to their ancient haunts in spring. Certain experience has been gained in the life of the race. Each generation has added to this store of experience, until the best places to winter in, and the most suitable to summer in, have been found. Thus the knowledge obtained from this experience has been ingrained, as it were, into the life of each individual. We call it "instinct," for want of a better term, but what is instinct if it is not the legacy bequeathed by experience?

But, it may well be asked, if this instinct of migration is the legacy of experience, which suggested to the bird that the best way to avoid complications of food supply and climate was to shift quarters, does not the "race" still continue to gain experience, in which case the instinct ought to show signs of modification? As an actual fact, we do find that certain modifications are taking place. Witness the woodcock, who has found it perfectly safe to resist the first promptings of his nature and stay to breed in a place to which he only came for a short visit. Again, the song-thrush and robin, which remain with us during the winter, are in most cases migrants. Almost every winter we get a number of bird casuals, driven

FIG. 10.—A LOVER OF MARSHES: THE JACK SNIPE.

This bird is about half the size of the common snipe.

here by stress of weather upon the Continent. The journeys that these birds make are doubtless indeterminate both with regard to manner and time, but in them we probably have the beginnings of some-

thing that will be determinate in both respects in the future.

Now, although these are supposititious views, they rest on a platform of facts. It is true that extremely few birds of existing species have hitherto been discovered in strata belonging to either the Miocene or Pliocene periods; but relics of several living quadrupeds show that the latter sojourned in the British islands before the Ice Age. So that, if they were enabled to survive by migrating southwards, how much easier would it have been for the feathered denizens to have done the same!

This attempt to explain the phenomena of the migratory movements of birds by having recourse to the records of former conditions of land and climate in the regions they now frequent is a striking illustration of the value of a knowledge of the past changes of the earth's surface in elucidating phenomena occurring around us; and whether or not they solve the difficulties of the case, no one can fairly dispute their significance. Lighthouses have been referred to as death-traps to the bird migrants. So they are; but out of evil will come good, now that these stations are used for collecting information as to bird habits. This really brilliant idea came first of all from the British Association, but now that America and Denmark have followed suit, much interesting and valuable information may be expected.

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